

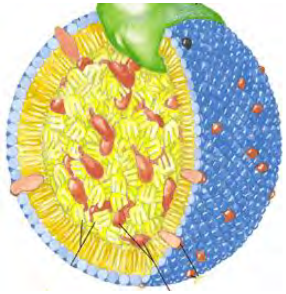


BIOCHEMISTRY REVIEW

Overview of Biomolecules

Chapter 8

Lipids





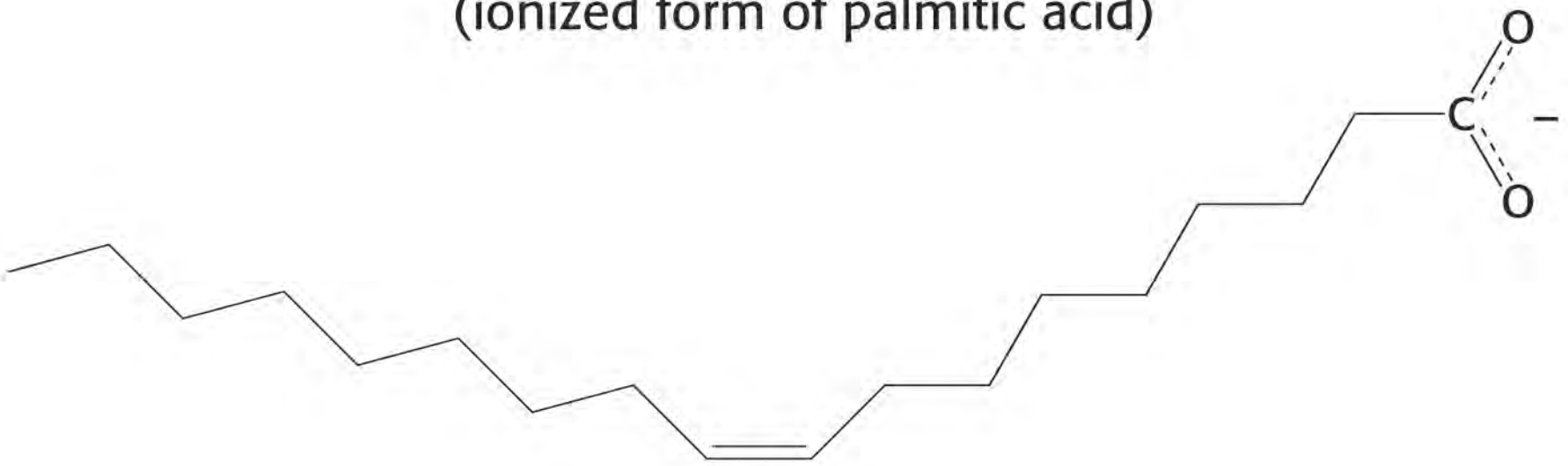
FATTY ACIDS

- **4-36 CARBONS**
- **ONE CARBOXYLIC ACID GROUP**
- **EVEN NUMBER OF CARBONS (USUALLY)**
- **LINEAR (USUALLY)**
- **SATURATED OR UNSATURATED**
- **CIS DOUBLE BONDS (USUALLY)**
- **UNCONJUGATED DOUBLE BONDS (USUALLY)**

  (- CH = CH – CH_2 – CH = CH -)



Palmitate
(ionized form of palmitic acid)



Oleate
(ionized form of oleic acid)

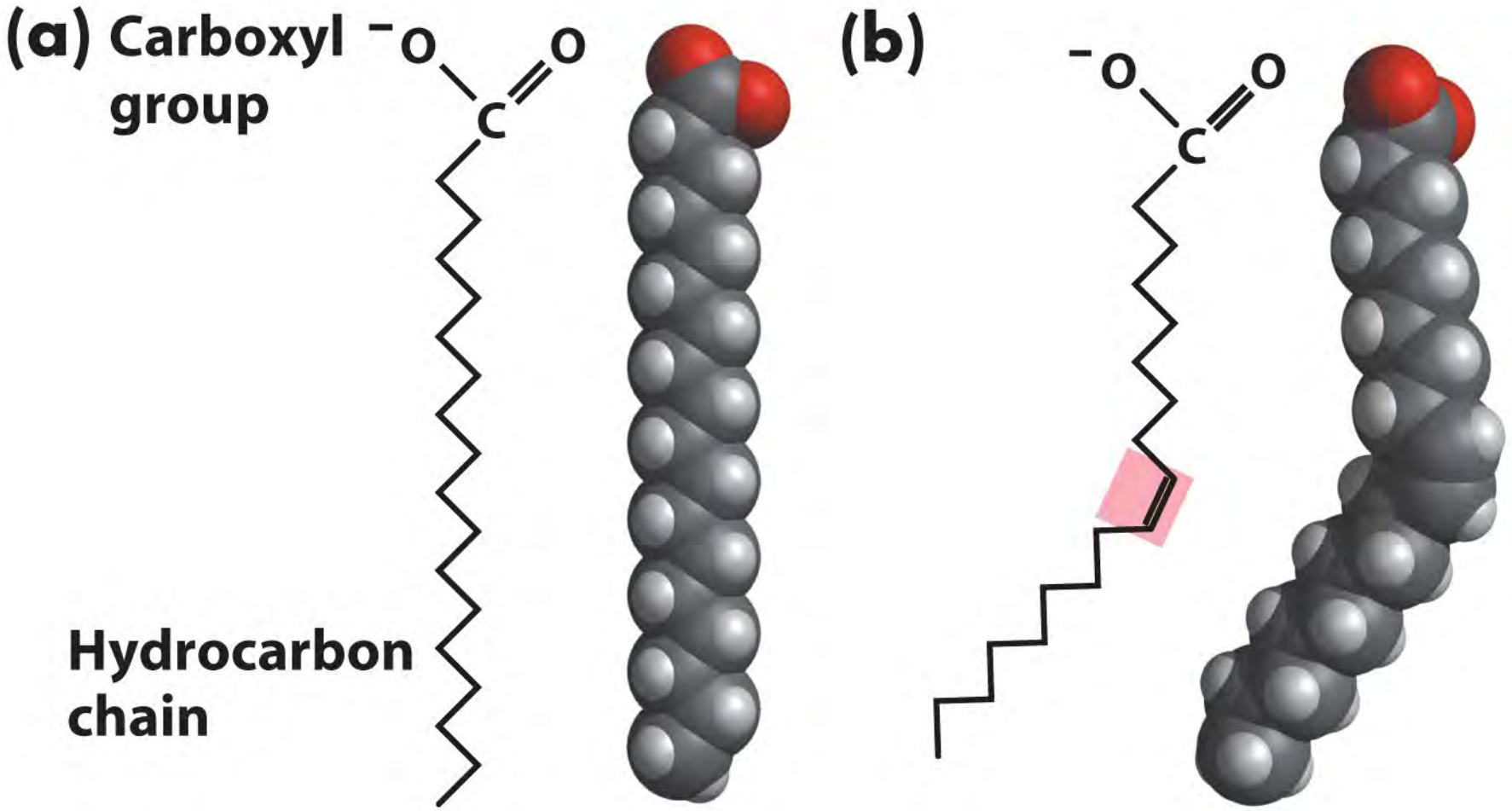

(a) Carboxyl group
Hydrocarbon chain
(b)

TABLE 12.1 Some naturally occurring fatty acids in animals

Number of carbons	Number of double bonds	Common name	Systematic name	Formula
12	0	Laurate	*n*-Dodecanoate	$CH_3(CH_2)_{10}COO^-$
14	0	Myristate	*n*-Tetradecanoate	$CH_3(CH_2)_{12}COO^-$
16	0	Palmitate	*n*-Hexadecanoate	$CH_3(CH_2)_{14}COO^-$
18	0	Stearate	*n*-Octadecanoate	$CH_3(CH_2)_{16}COO^-$
20	0	Arachidate	*n*-Eicosanoate	$CH_3(CH_2)_{18}COO^-$
22	0	Behenate	*n*-Docosanoate	$CH_3(CH_2)_{20}COO^-$
24	0	Lignocerate	*n*-Tetracosanoate	$CH_3(CH_2)_{22}COO^-$
16	1	Palmitoleate	*cis*-Δ^9-Hexadecenoate	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COO^-$
18	1	Oleate	*cis*-Δ^9-Octadecenoate	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COO^-$
18	2	Linoleate	*cis,cis*-Δ^9,Δ^{12}-Octadecadienoate	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COO^-$
18	3	Linolenate	all-*cis*-$\Delta^9,\Delta^{12},\Delta^{15}$-Octadecatrienoate	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COO^-$
20	4	Arachidonate	all-*cis*-$\Delta^5,\Delta^8,\Delta^{11},\Delta^{14}$-Eicosatetraenoate	$CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COO^-$



Are You Getting It??



Which is the most likely structure for a common fatty acid?

a) $CH_3(CH_2)_{15}COOH$
b) $HOOC(CH_2)_{14}COOH$
c) $(CH_3)_2CH(CH_2)_{13}COOH$
d) $CH_3(CH_2)_9CH{=}CH(CH_2)_3COOH$
e) $CH_3(CH_2)_6CH{=}CH{-}CH{=}CH(CH_2)_4COOH$



Are You Getting It??



Answer

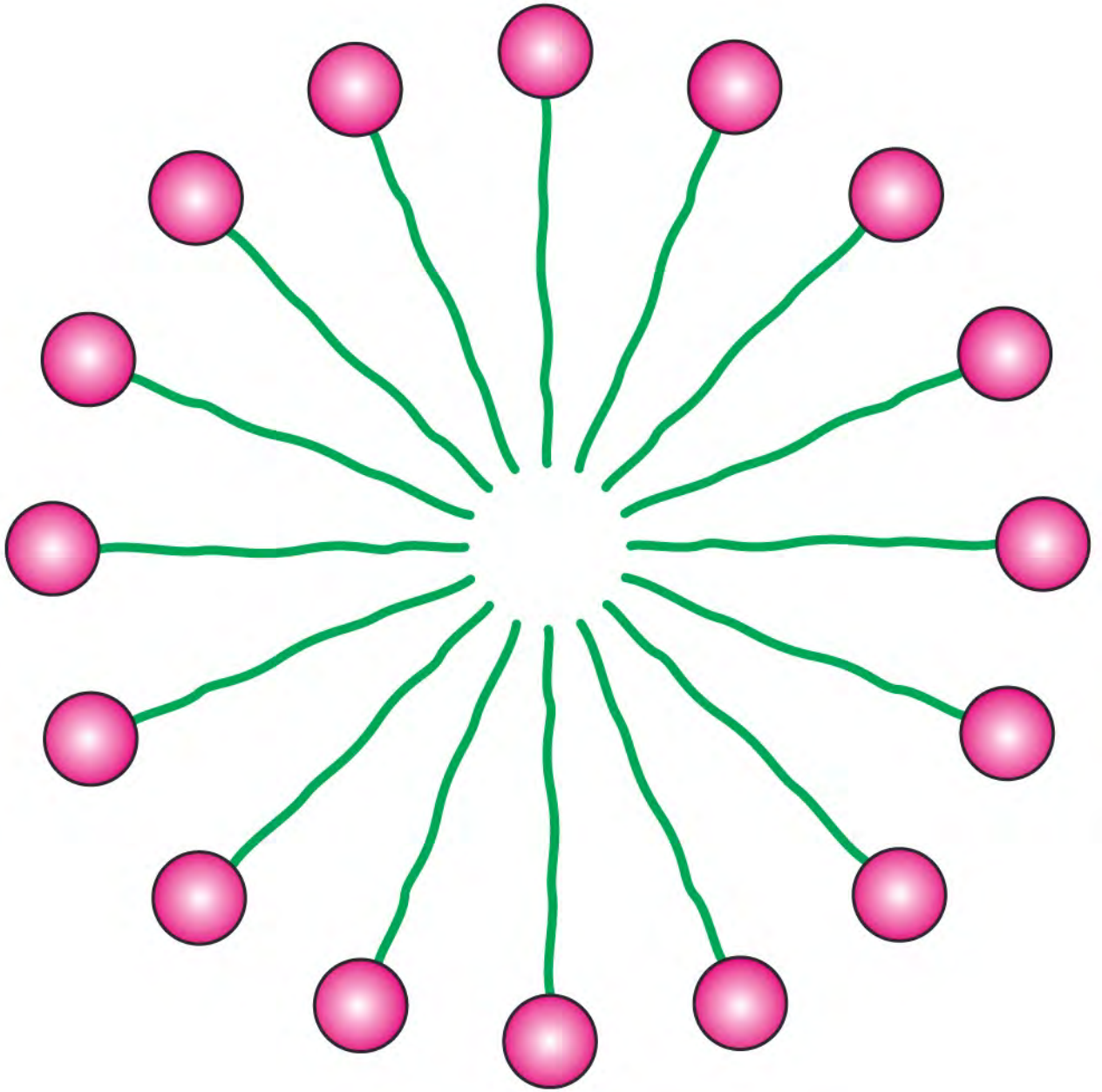
Which is the most likely structure for a common fatty acid?

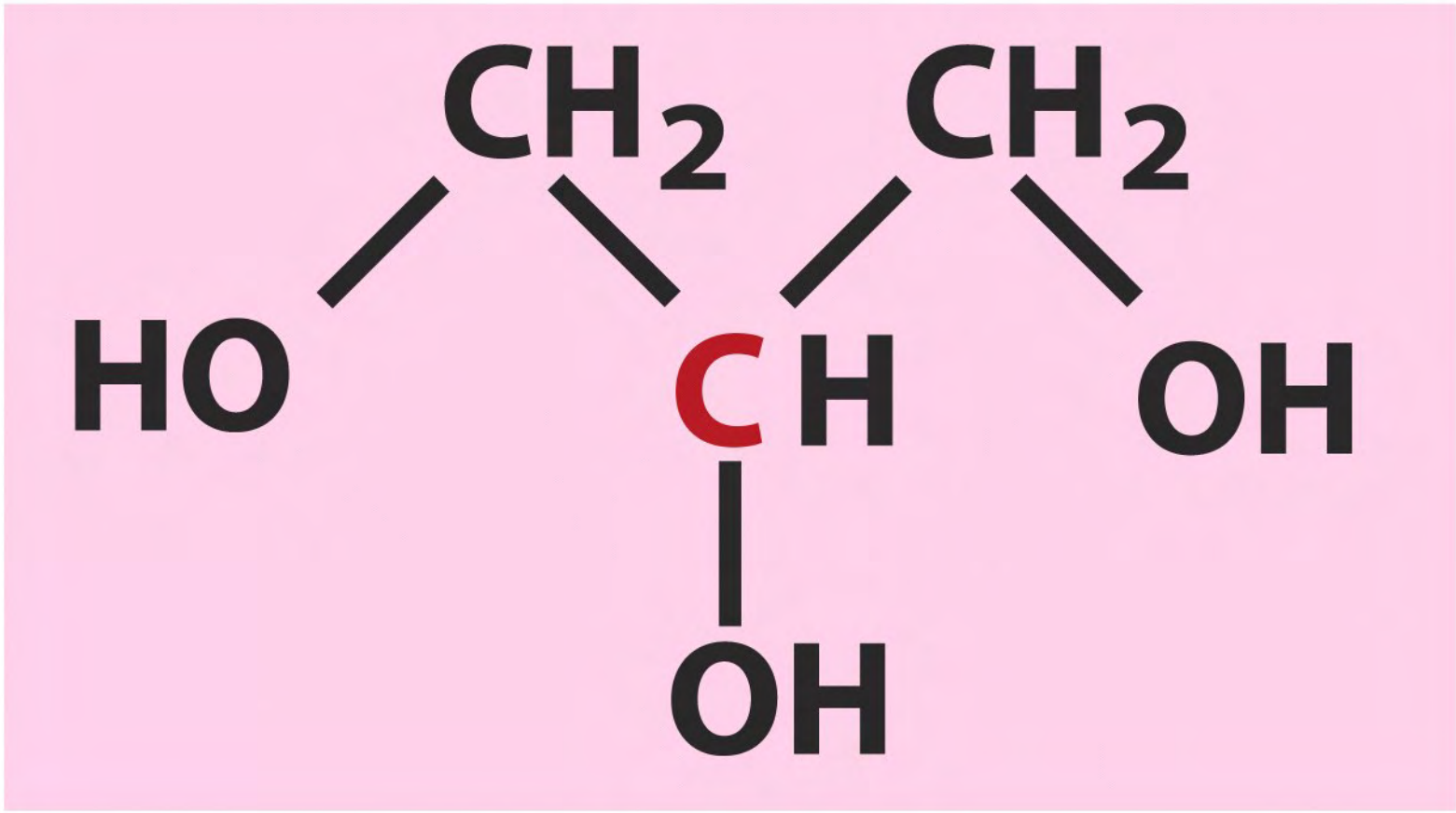
a) $CH_3(CH_2)_{15}COOH$
b) $HOOC(CH_2)_{14}COOH$
c) $(CH_3)_2CH(CH_2)_{13}COOH$
d) *$CH_3(CH_2)_9CH{=}CH(CH_2)_3COOH$*
e) $CH_3(CH_2)_6CH{=}CH{-}CH{=}CH(CH_2)_4COOH$

FATTY ACID SALT (SOAP)

$$CH_3(CH_2)_{16}COOH + NaOH \rightarrow$$

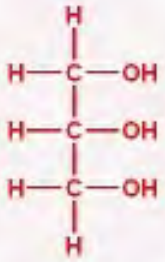
$$CH_3(CH_2)_{16}COO^-Na^+ + H_2O$$





Glycerol

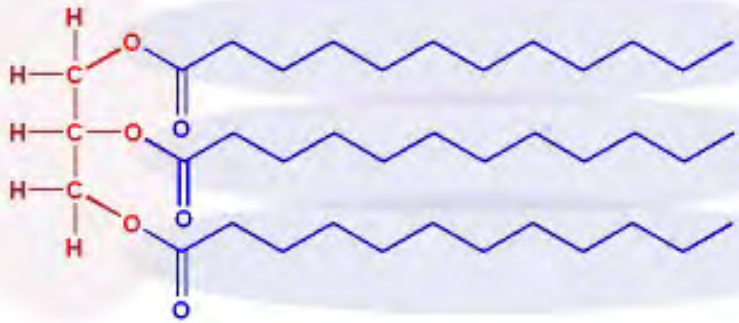
Glycerol

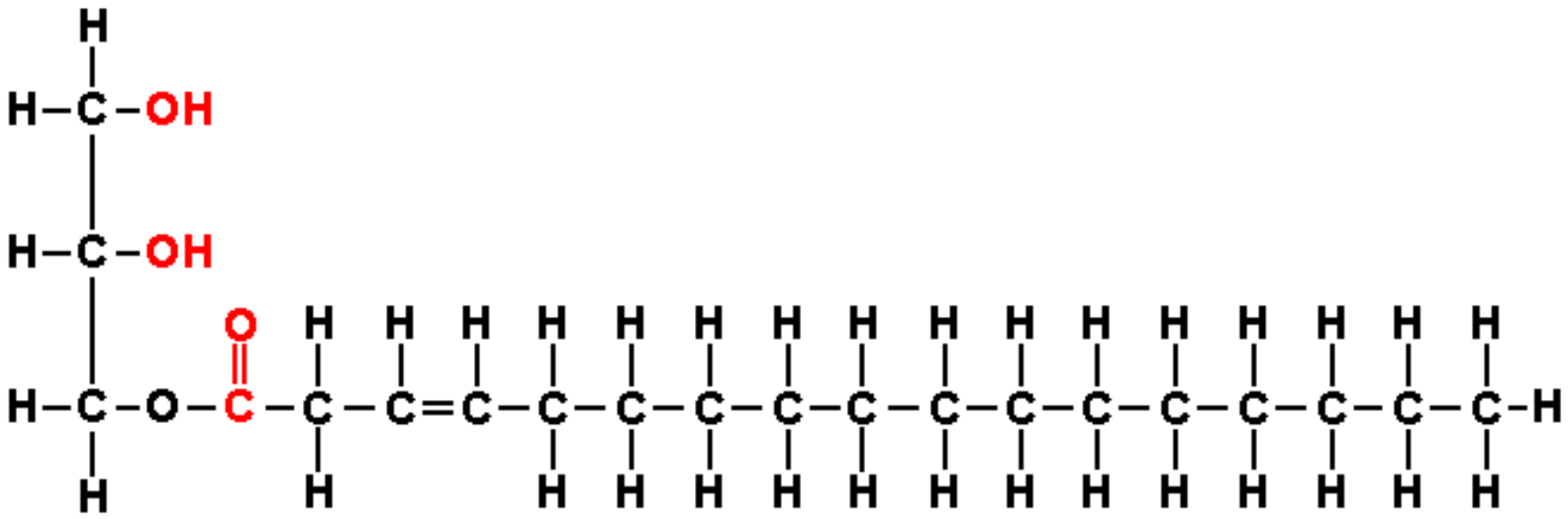


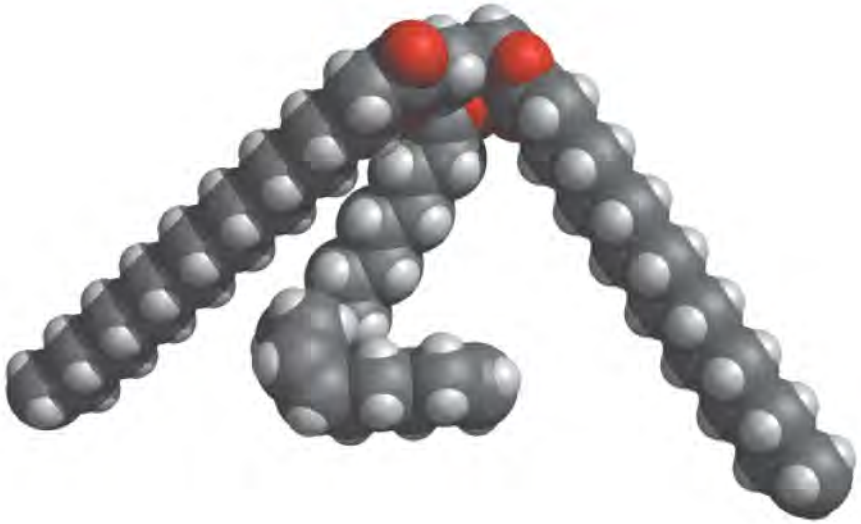
A "free" Fatty Acid

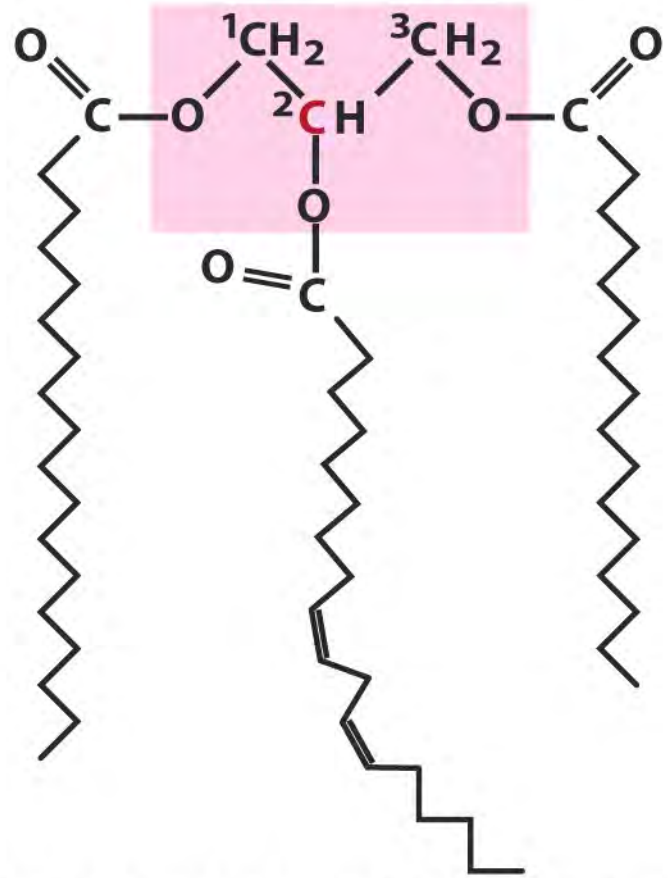


Triglyceride



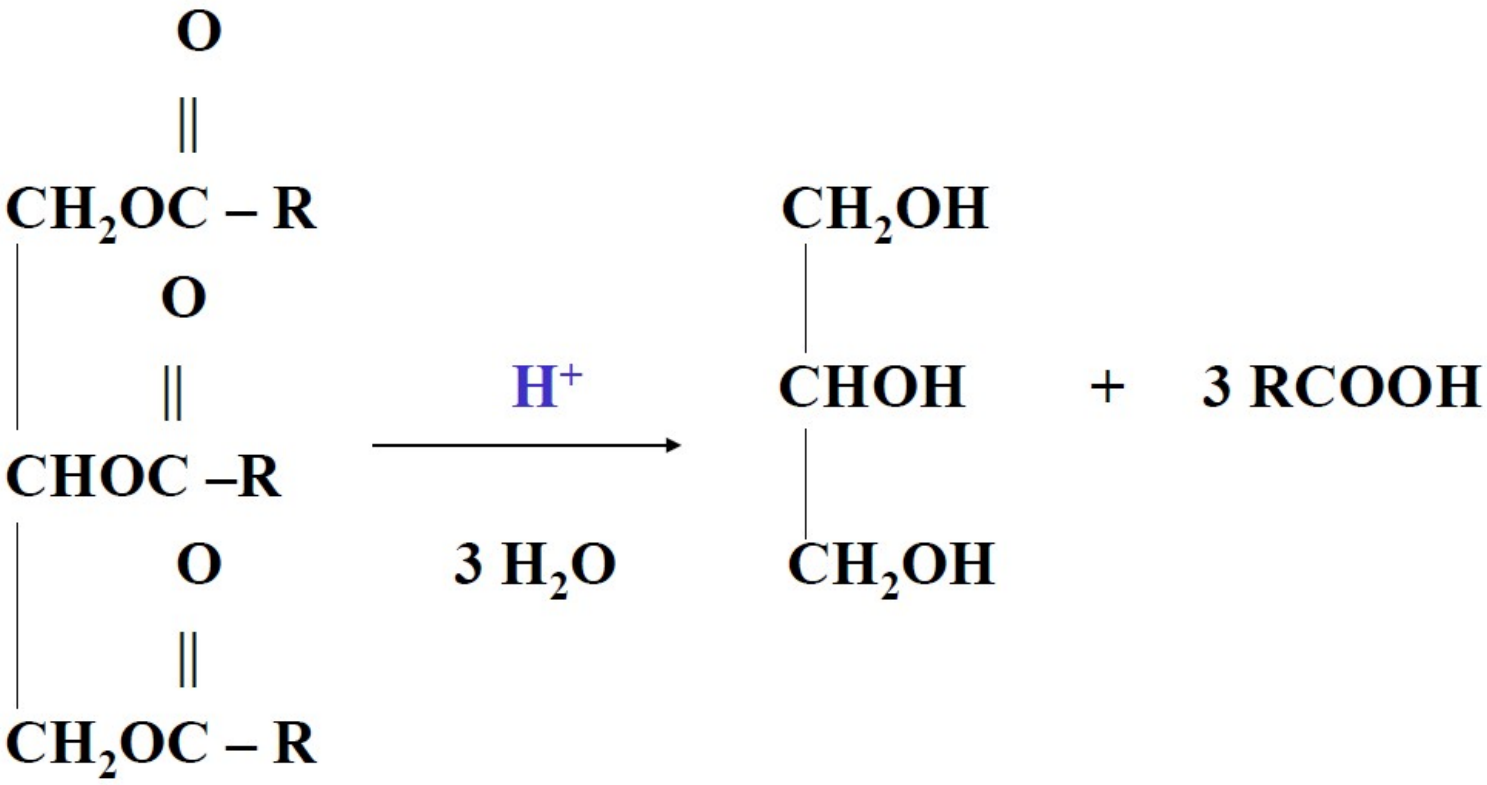






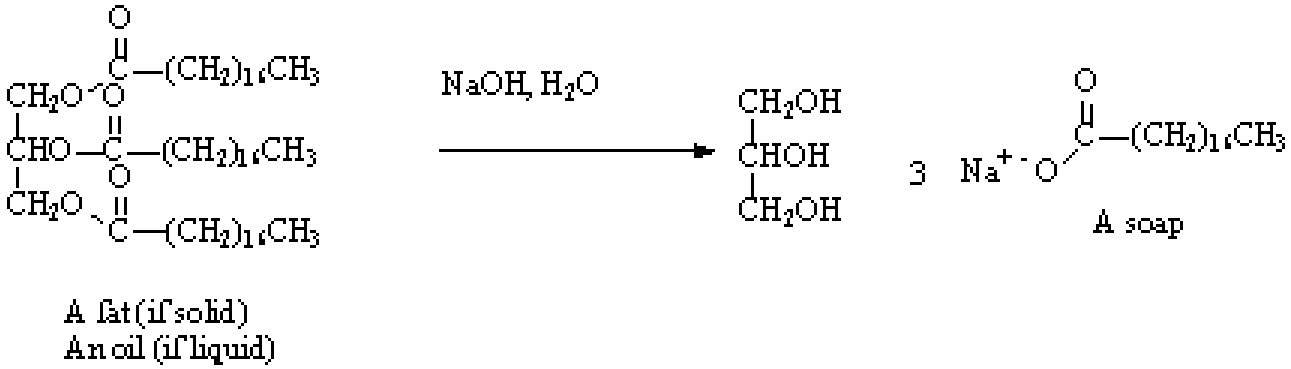
1-Stearoyl, 2-linoleoyl, 3-palmitoyl glycerol, a mixed triacylglycerol

ACID HYDROLYSIS OF A TRIGLYCERIDE



Saponification

- Base catalyzed hydrolysis is called "saponification"



A fat (if solid)
An oil (if liquid)



Are You Getting It??



Which properties are characteristic of triglycerides?
(multiple answers)

a) They contain one glycerol molecule.
b) They contain three -COOH groups.
c) They contain three ester bonds.
d) They can be saponified in acid.
e) They can be hydrolyzed in base.
f) They are amphipathic.



Are You Getting It??



Answer

Which properties are characteristic of triglycerides?

a) ***They contain one glycerol molecule.***

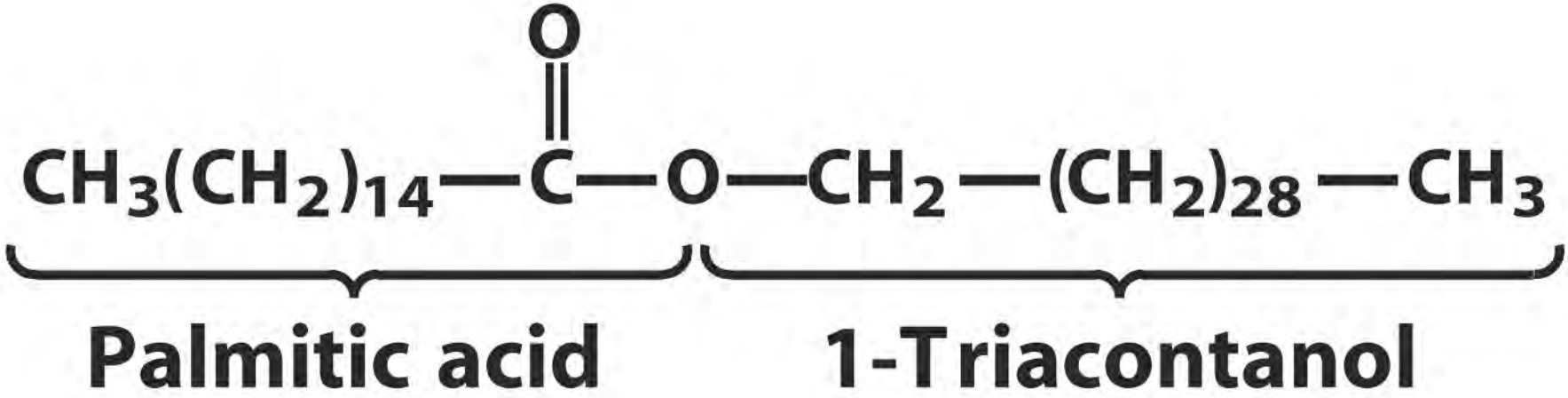
b) **They contain three -COOH groups.**

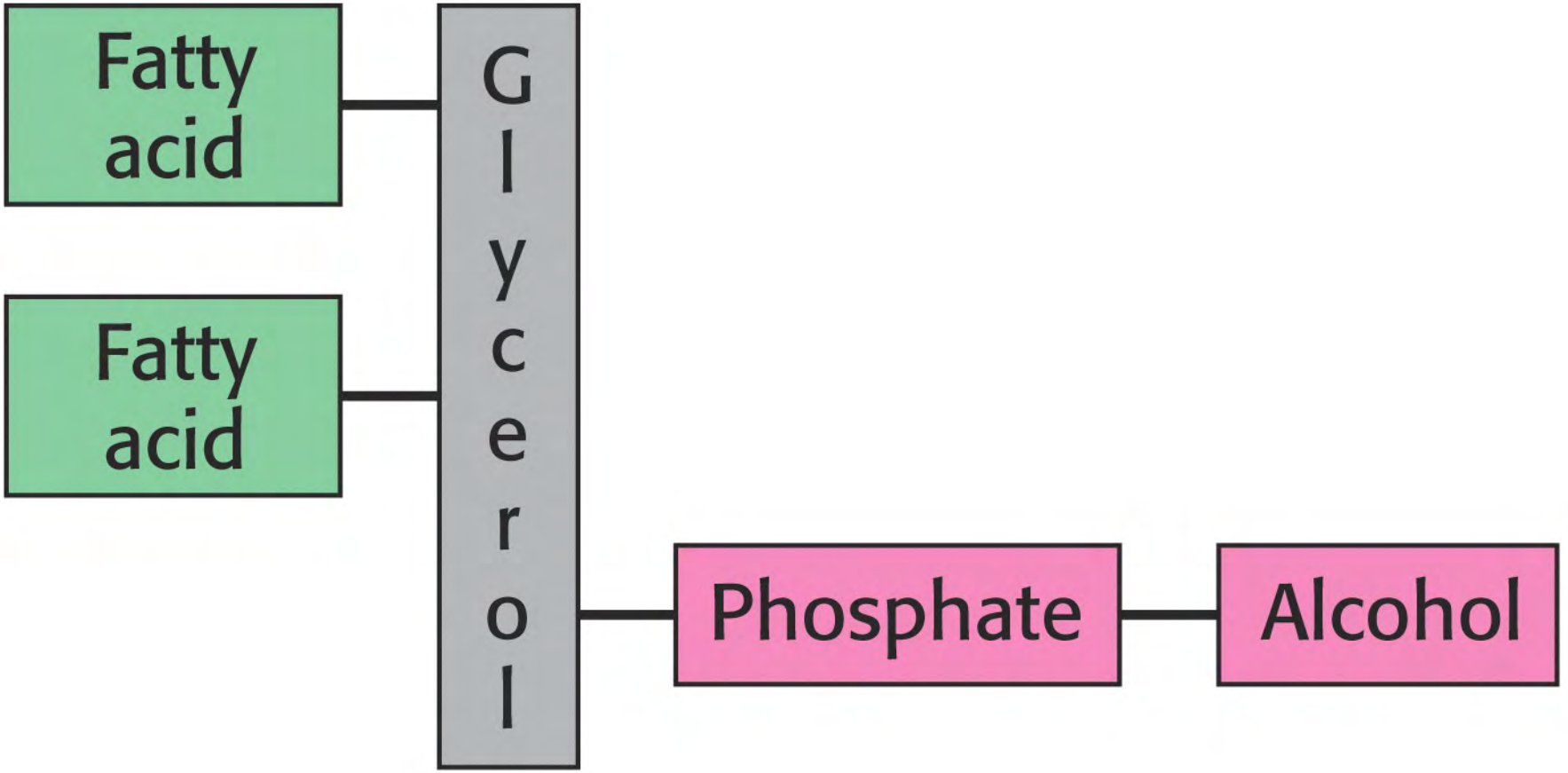
c) ***They contain three ester bonds.***

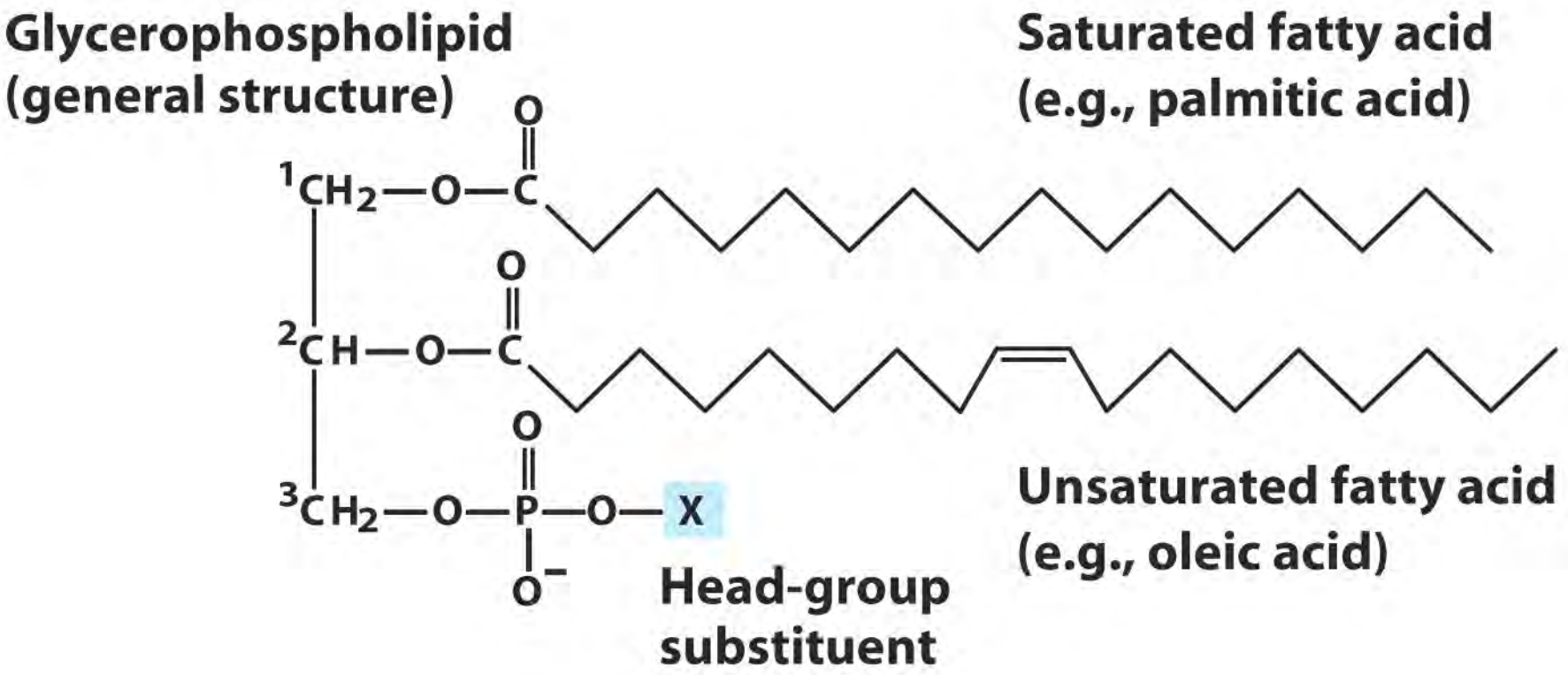
d) **They can be saponified in acid.**

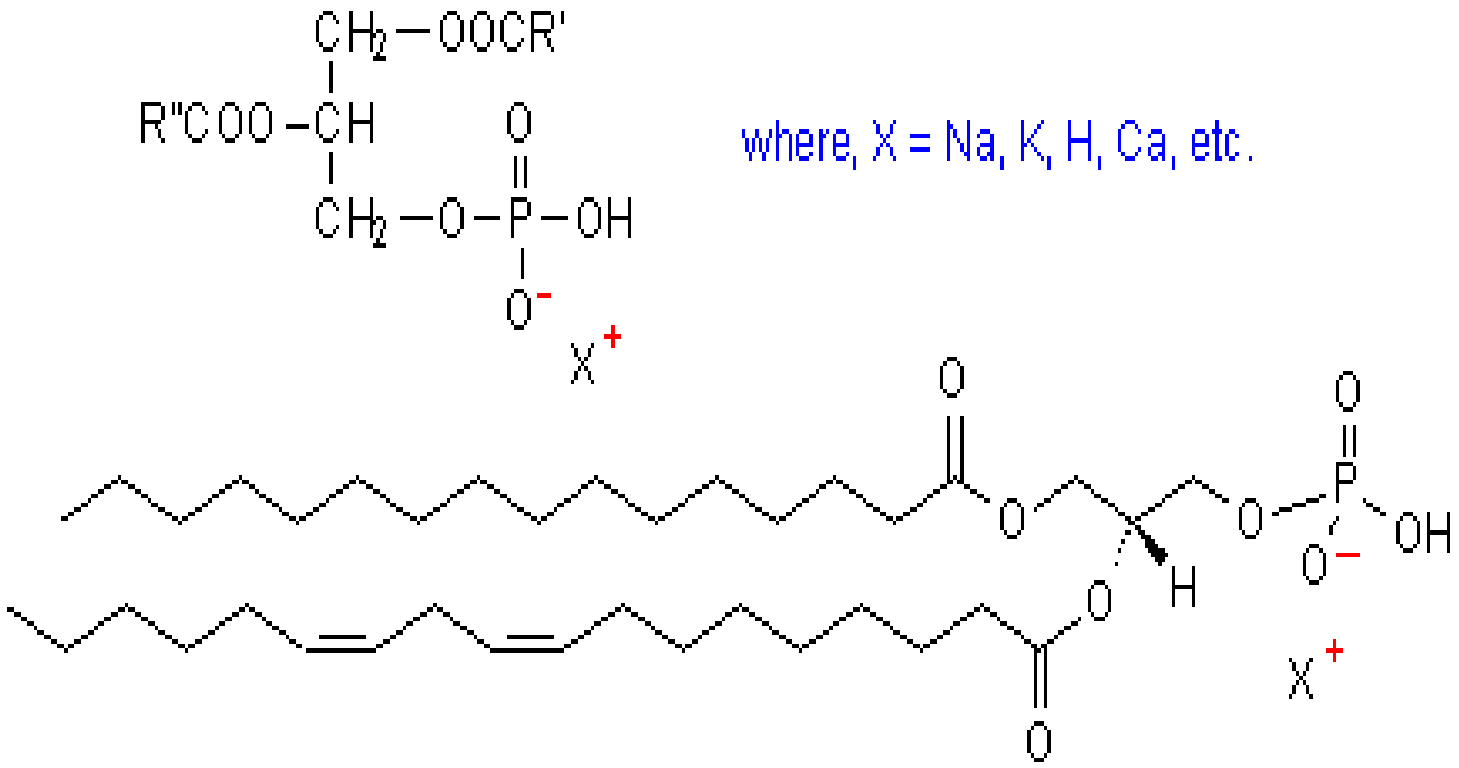
e) ***They can be hydrolyzed in base.***

f) **They are amphipathic.**


O
CH3(CH2)14—C—O—CH2—(CH2)28—CH3
Palmitic acid
1-Triacontanol

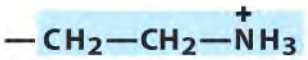
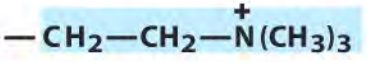
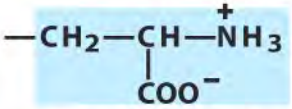
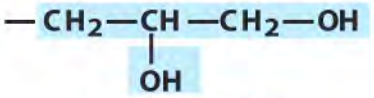
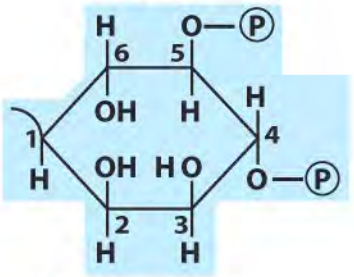
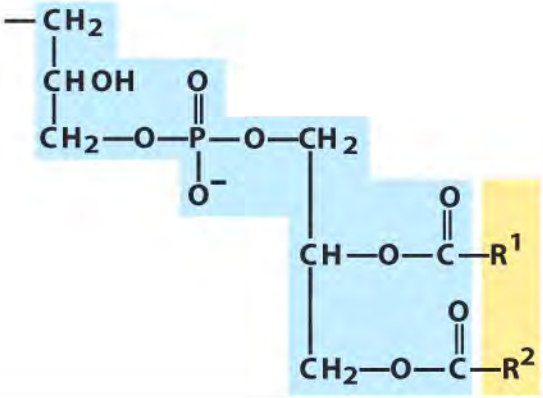

Fatty acid
Fatty acid
Glycerol
Phosphate
Alcohol

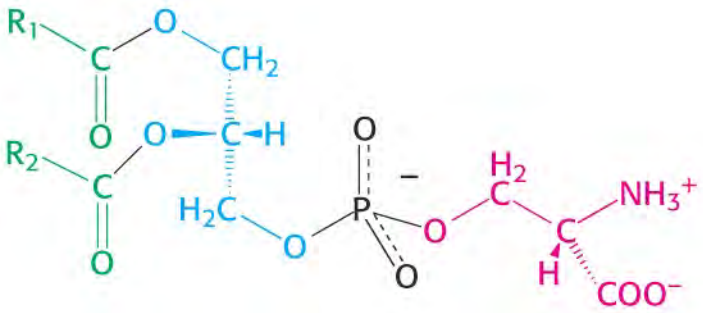

Glycerophospholipid
(general structure)
Saturated fatty acid
(e.g., palmitic acid)
Unsaturated fatty acid
(e.g., oleic acid)
Head-group
substituent
X



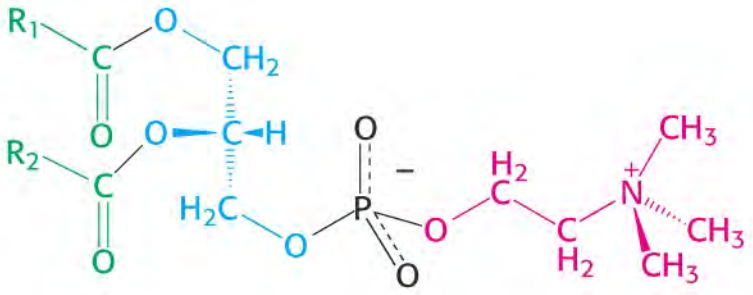
1-hexadecanoyl, 2-(9Z,12Z-octadecadienoyl)-*sn*-glycero-3-phosphate

(phosphatidic acid)

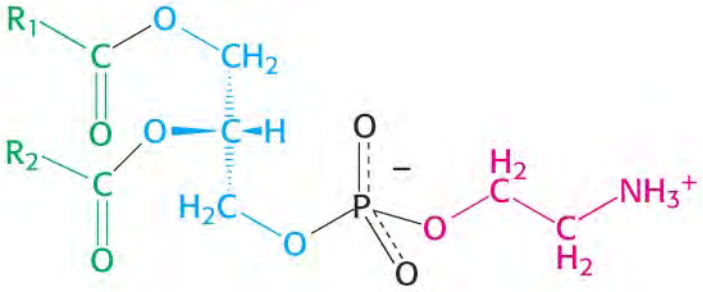
Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—		−1
Phosphatidylethanolamine	Ethanolamine		0
Phosphatidylcholine	Choline		0
Phosphatidylserine	Serine		−1
Phosphatidylglycerol	Glycerol		−1
Phosphatidylinositol 4,5-bisphosphate	*myo*-Inositol 4,5-bisphosphate		−4
Cardiolipin	Phosphatidyl-glycerol		−2



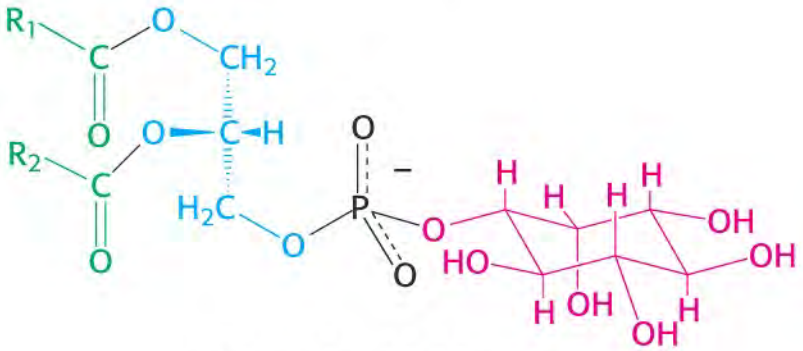
Phosphatidyl serine



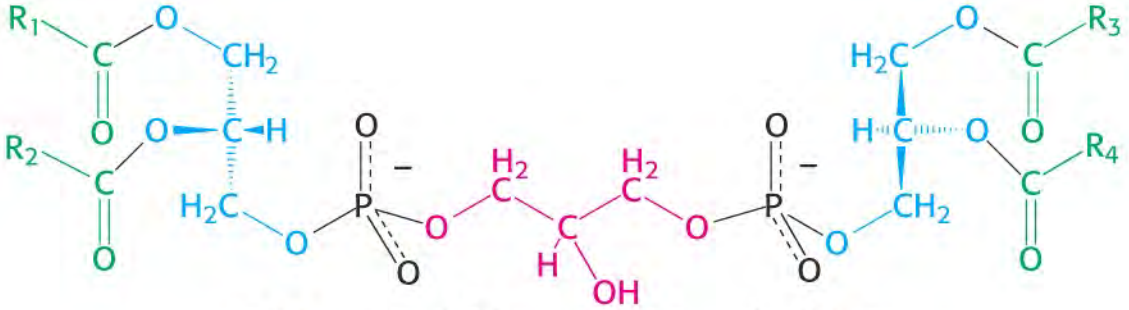
Phosphatidyl choline



Phosphatidyl ethanolamine



Phosphatidyl inositol



Diphosphatidyl glycerol (cardiolipin)



Are You Getting It??



Which properties are characteristic of glycerophospholipids? ***(multiple answers)***

a) They can contain two different fatty acids.
b) They contain a polar group such as serine.
c) They can be positively charged.
d) They are saponifiable.
e) They are amphipathic.



Are You Getting It??



Answer

Which properties are characteristic of glycerophospholipids?

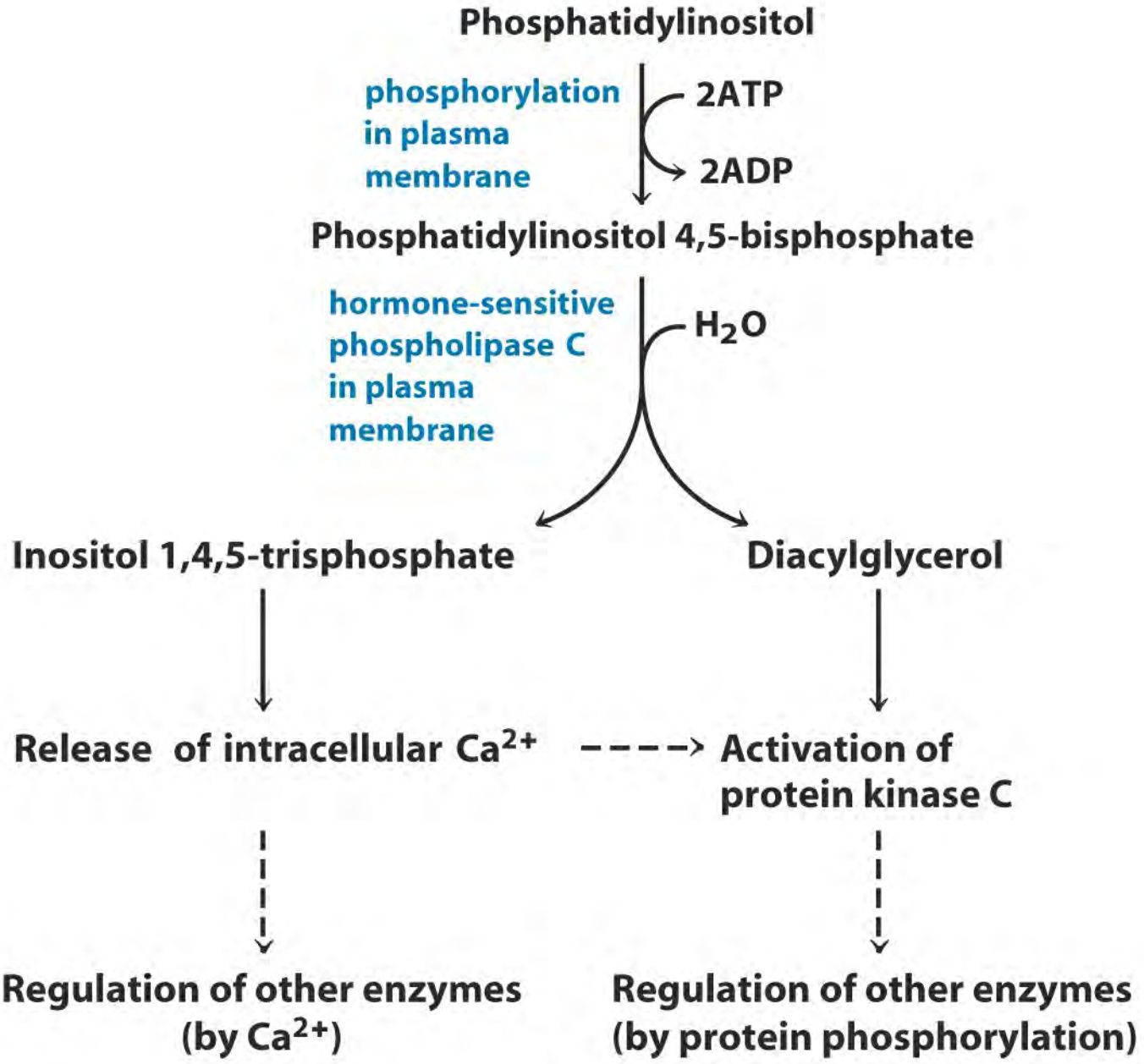
a) ***They can contain two different fatty acids.***

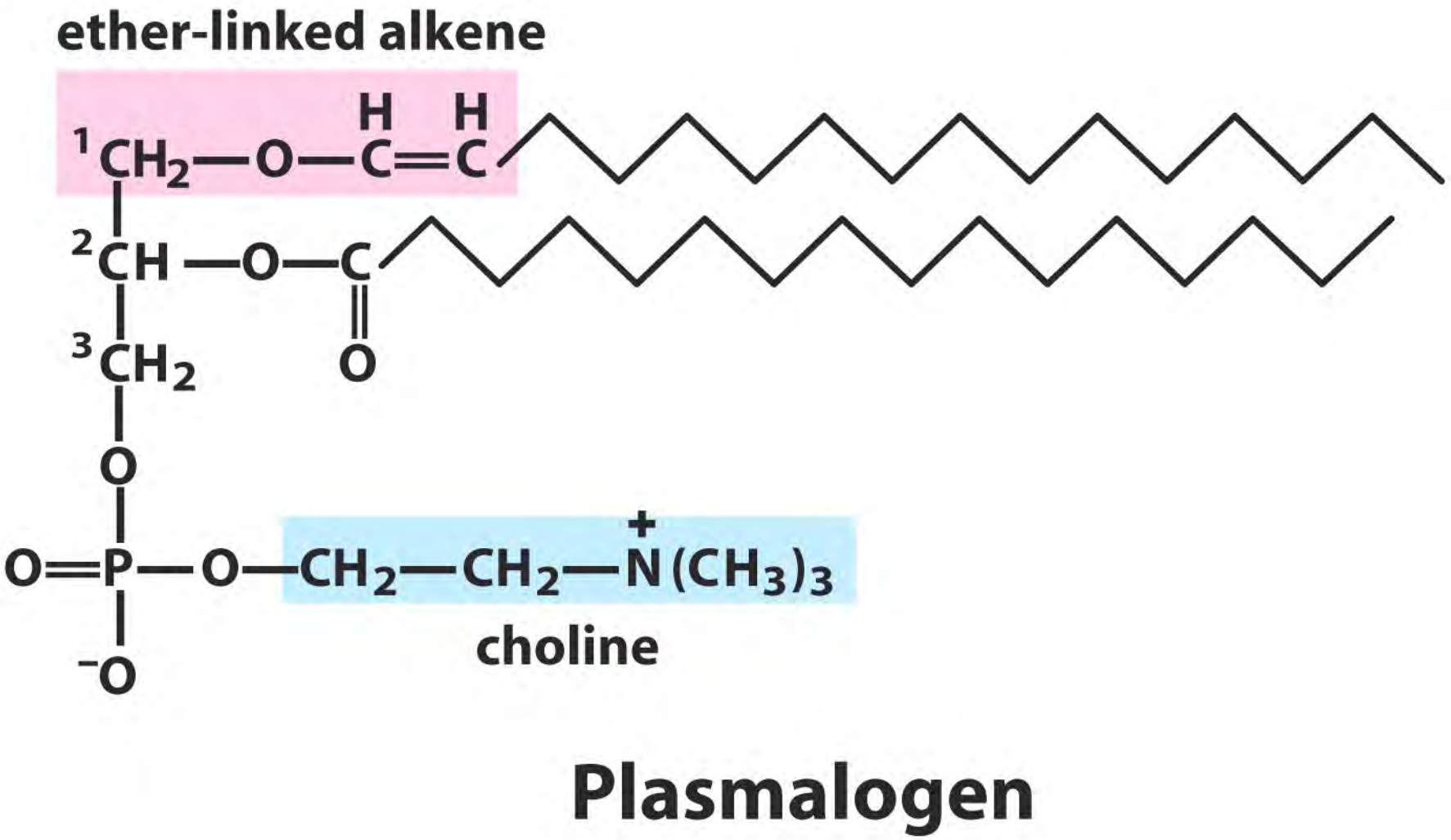
b) ***They contain a polar group such as serine.***

c) **They can be positively charged.**

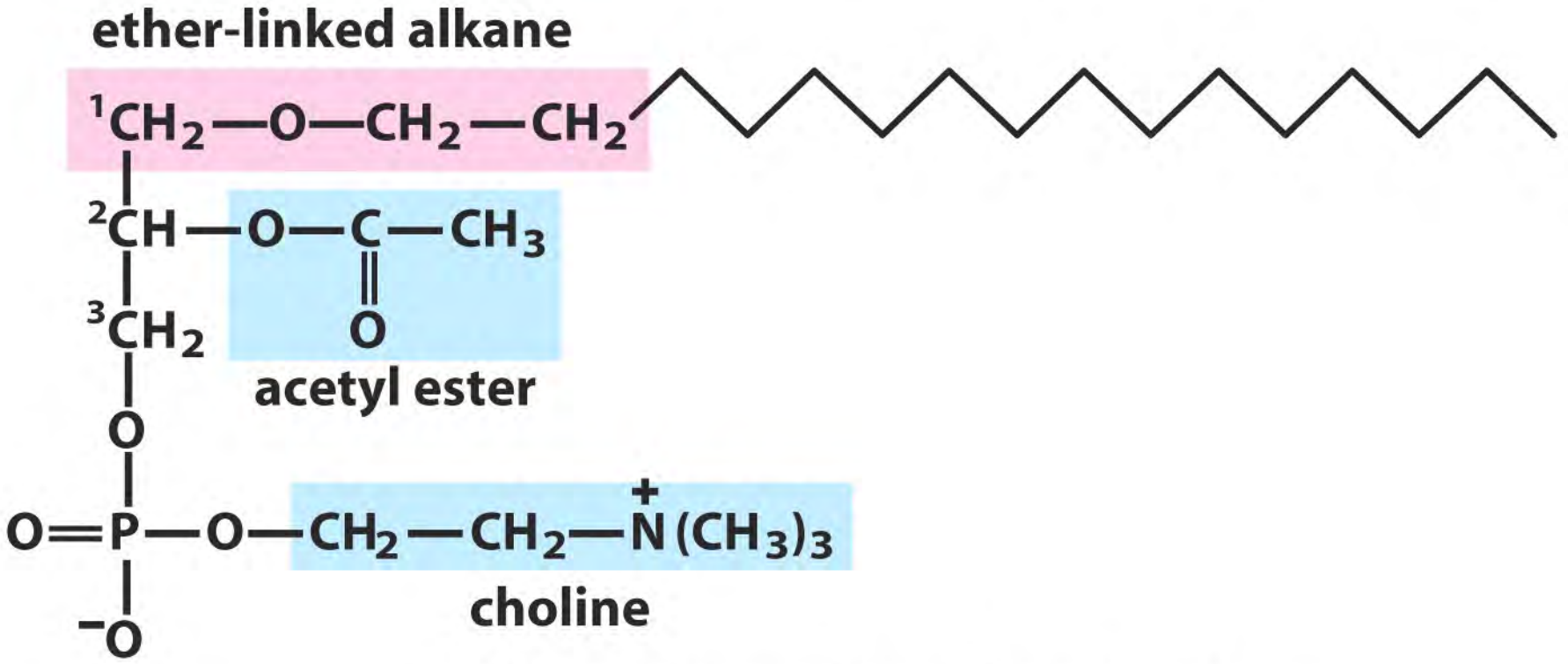
d) ***They are saponifiable.***

e) ***They are amphipathic.***

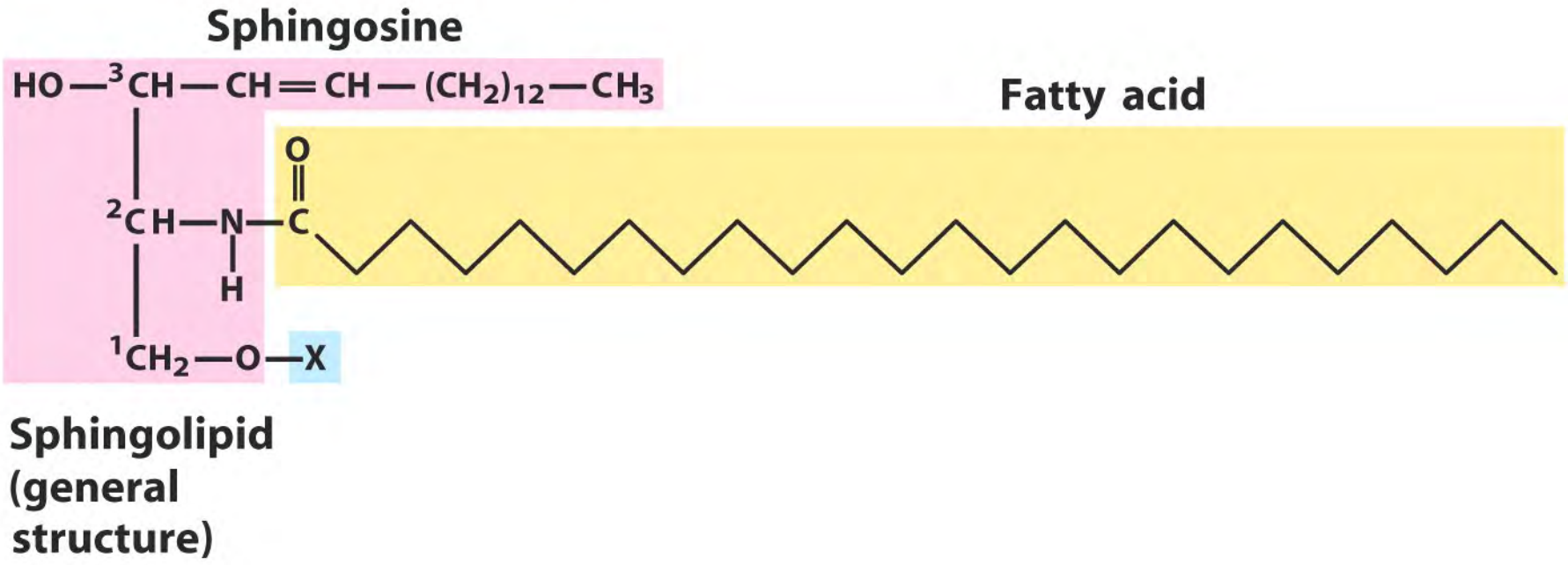

Phosphatidylinositol
phosphorylation in plasma membrane
2ATP
2ADP
Phosphatidylinositol 4,5-bisphosphate
hormone-sensitive phospholipase C in plasma membrane
H_2O
Inositol 1,4,5-trisphosphate
Diacylglycerol
Release of intracellular Ca^{2+}
Activation of protein kinase C
Regulation of other enzymes (by Ca^{2+})
Regulation of other enzymes (by protein phosphorylation)

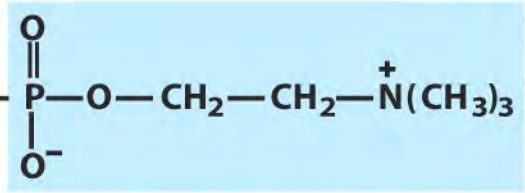
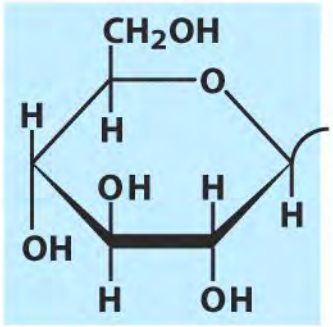
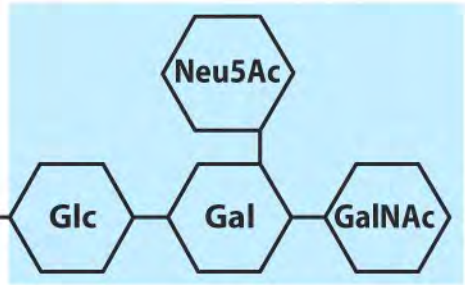


Plasmalogen



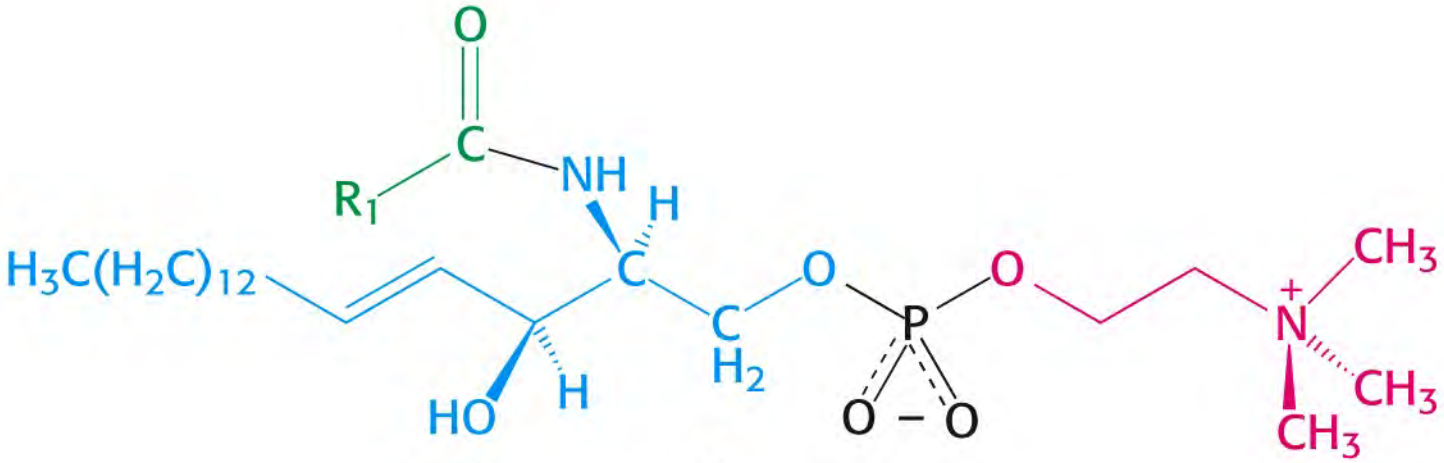
Platelet-activating factor


Sphingosine
HO—3CH—CH=CH—(CH2)12—CH3
Fatty acid
O
2CH—N—C
H
1CH2—O—X
Sphingolipid
(general
structure)

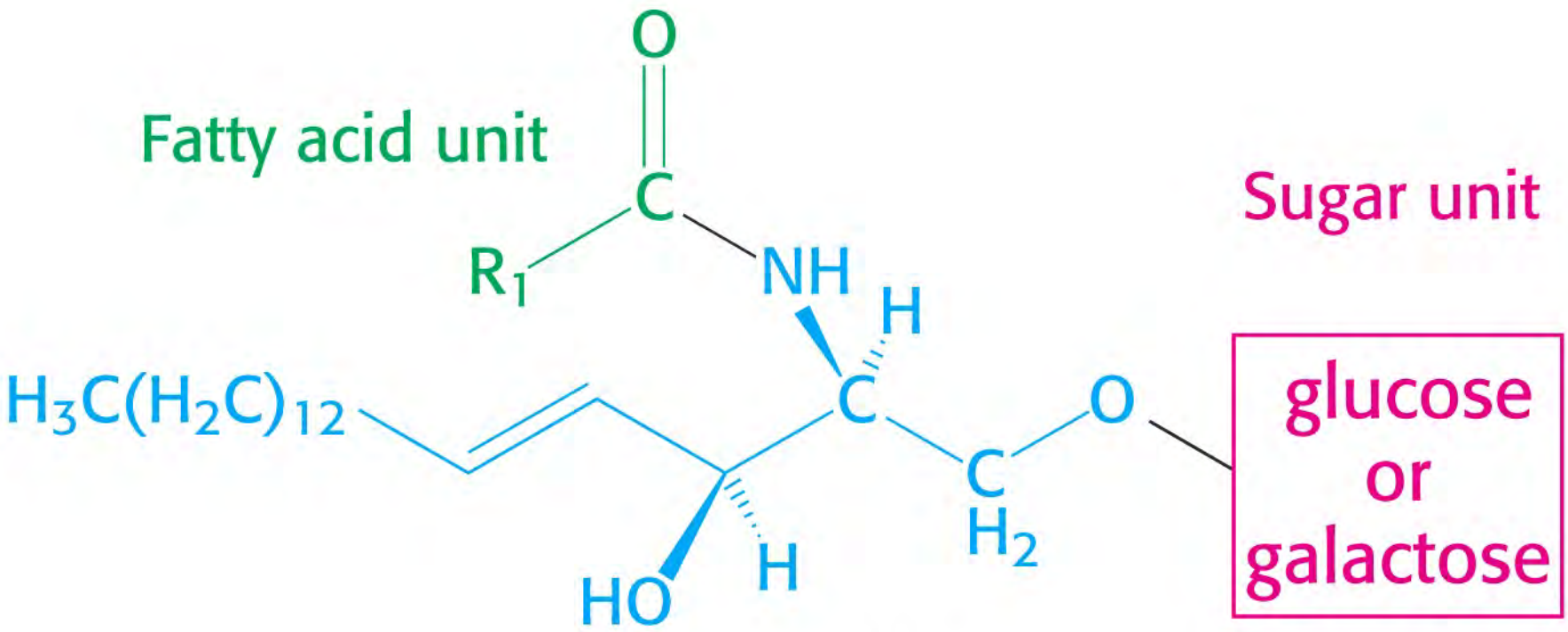
Name of sphingolipid	Name of X	Formula of X
Ceramide	—	— H
Sphingomyelin	Phosphocholine	
Neutral glycolipids Glucosylcerebroside	Glucose	
Lactosylceramide (a globoside)	Di-, tri-, or tetrasaccharide	
Ganglioside GM2	Complex oligosaccharide	



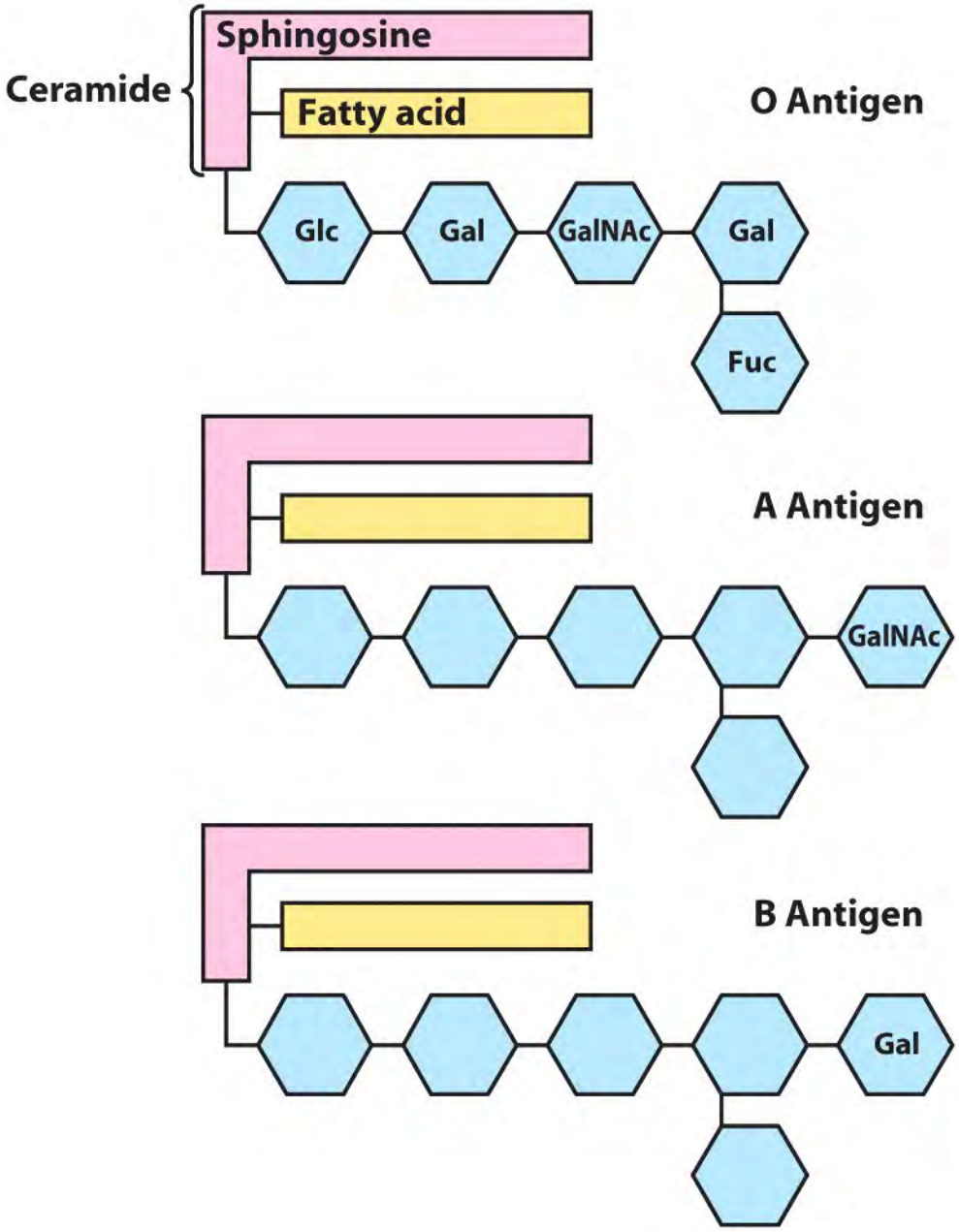
Sphingosine



Sphingomyelin



Cerebroside
(a glycolipid)


Ceramide
Sphingosine
Fatty acid
O Antigen
Glc
Gal
GalNAc
Gal
Fuc
A Antigen
GalNAc
B Antigen
Gal



Are You Getting It??



Which properties are characteristic of sphingolipids?
(multiple answers)

a) All sphingolipids contain an amino alcohol.
b) All sphingolipids contain phosphate.
c) All sphingolipids contain a fatty acid.
d) All sphingolipids contain a carbohydrate.
e) All sphingolipids are amphipathic.
f) All sphingolipids are saponifiable.



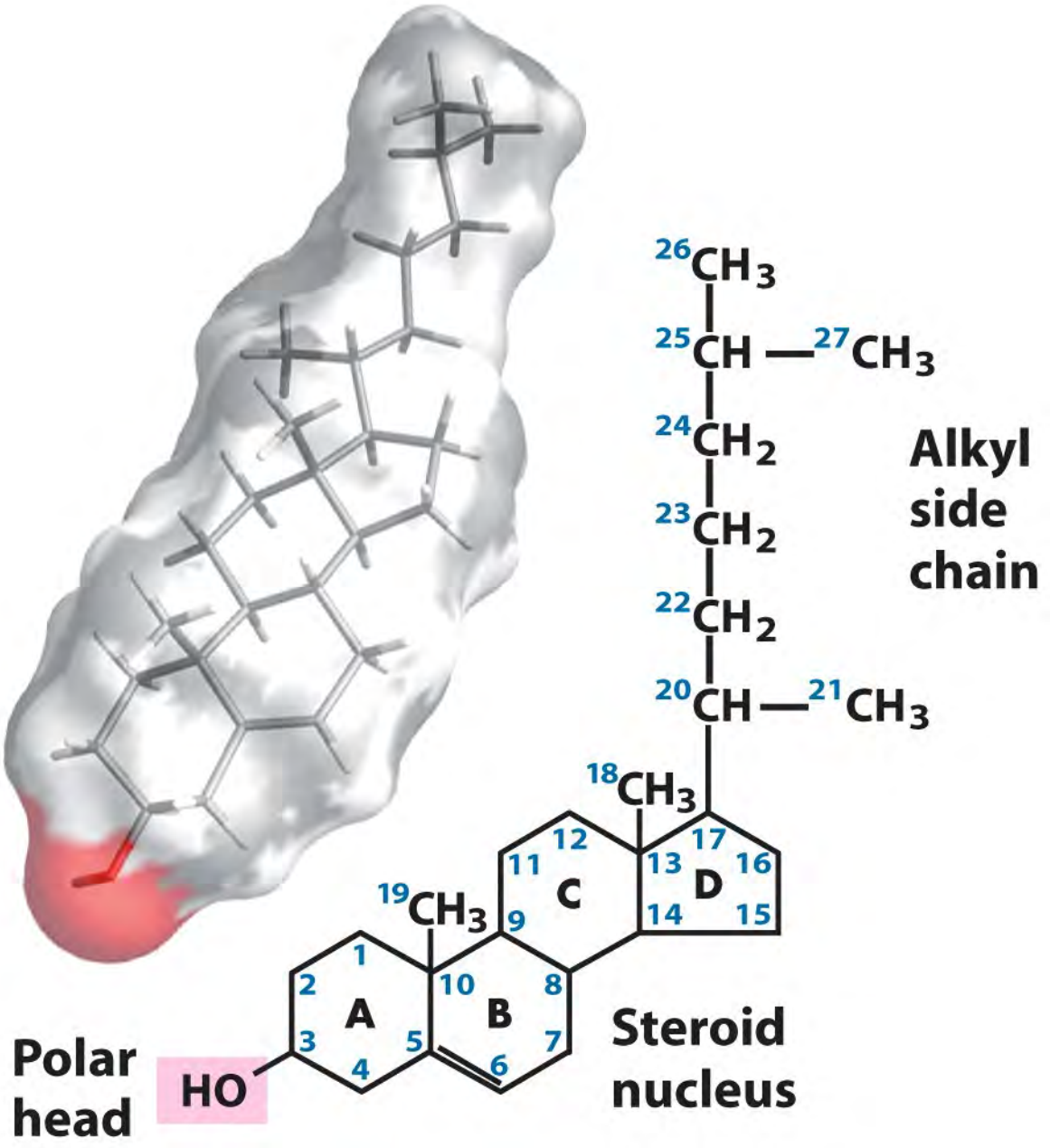
Are You Getting It??

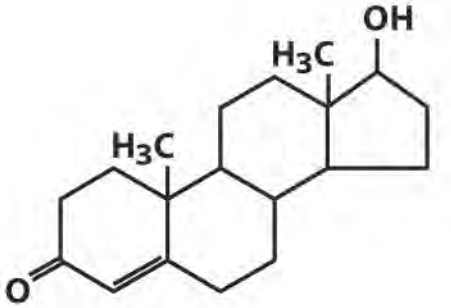


Answer

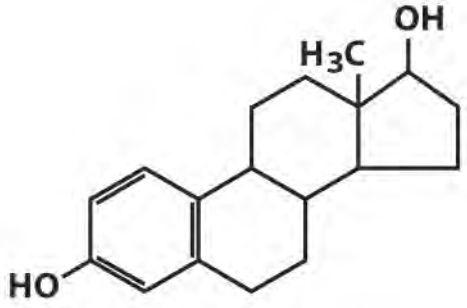
Which properties are characteristic of sphingolipids?

a) ***All sphingolipids contain an amino alcohol.***
b) **All sphingolipids contain phosphate.**
c) ***All sphingolipids contain a fatty acid.***
d) **All sphingolipids contain a carbohydrate.**
e) ***All sphingolipids are amphipathic.***
f) ***All sphingolipids are saponifiable.***

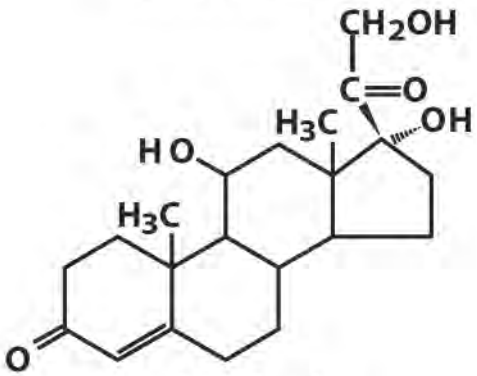

26CH3
25CH —27CH3
24CH2
23CH2
22CH2
20CH —21CH3
Alkyl side chain
18CH3
19CH3
A
B
C
D
HO
Polar head
Steroid nucleus



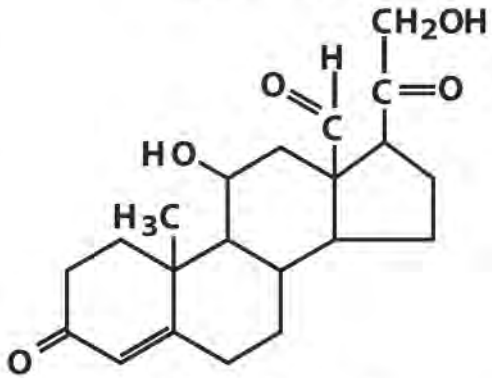
Testosterone



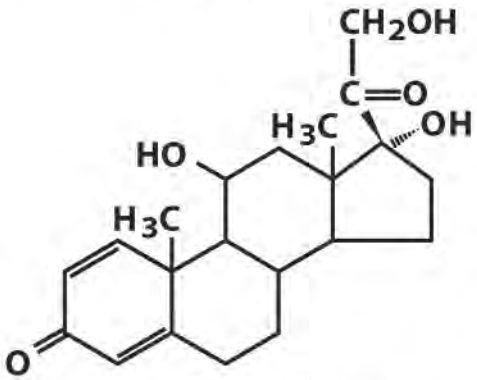
Estradiol



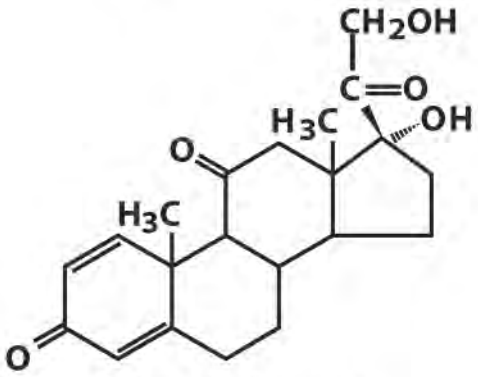
Cortisol



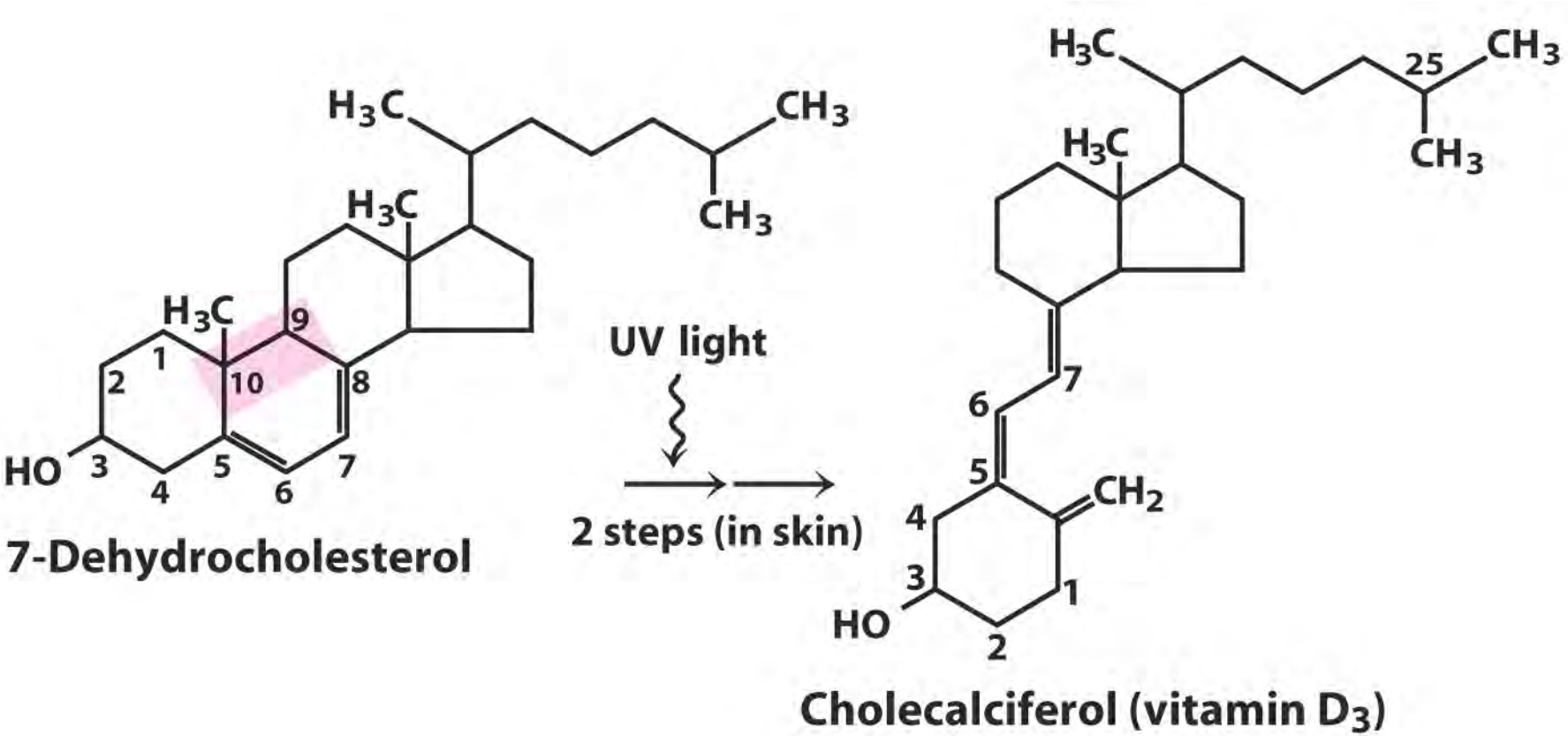
Aldosterone



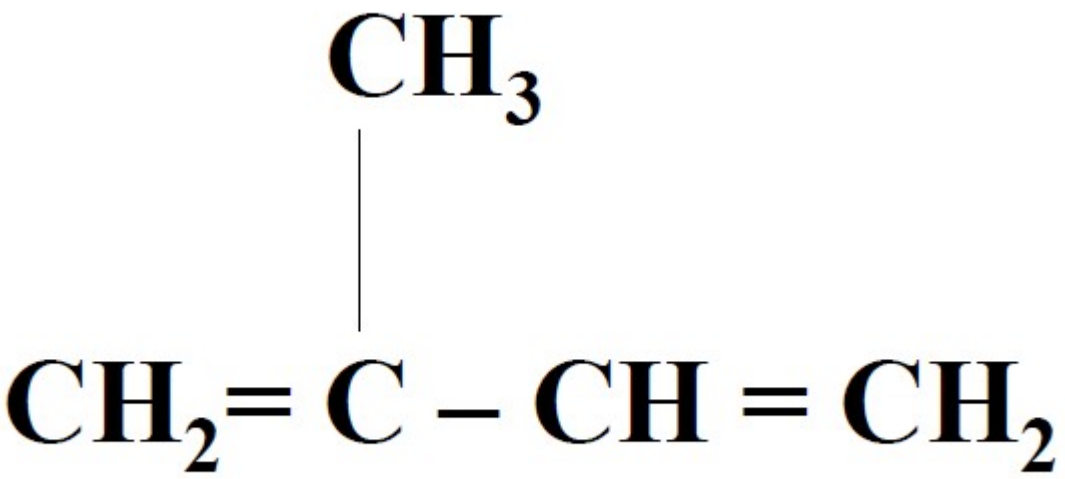
Prednisolone

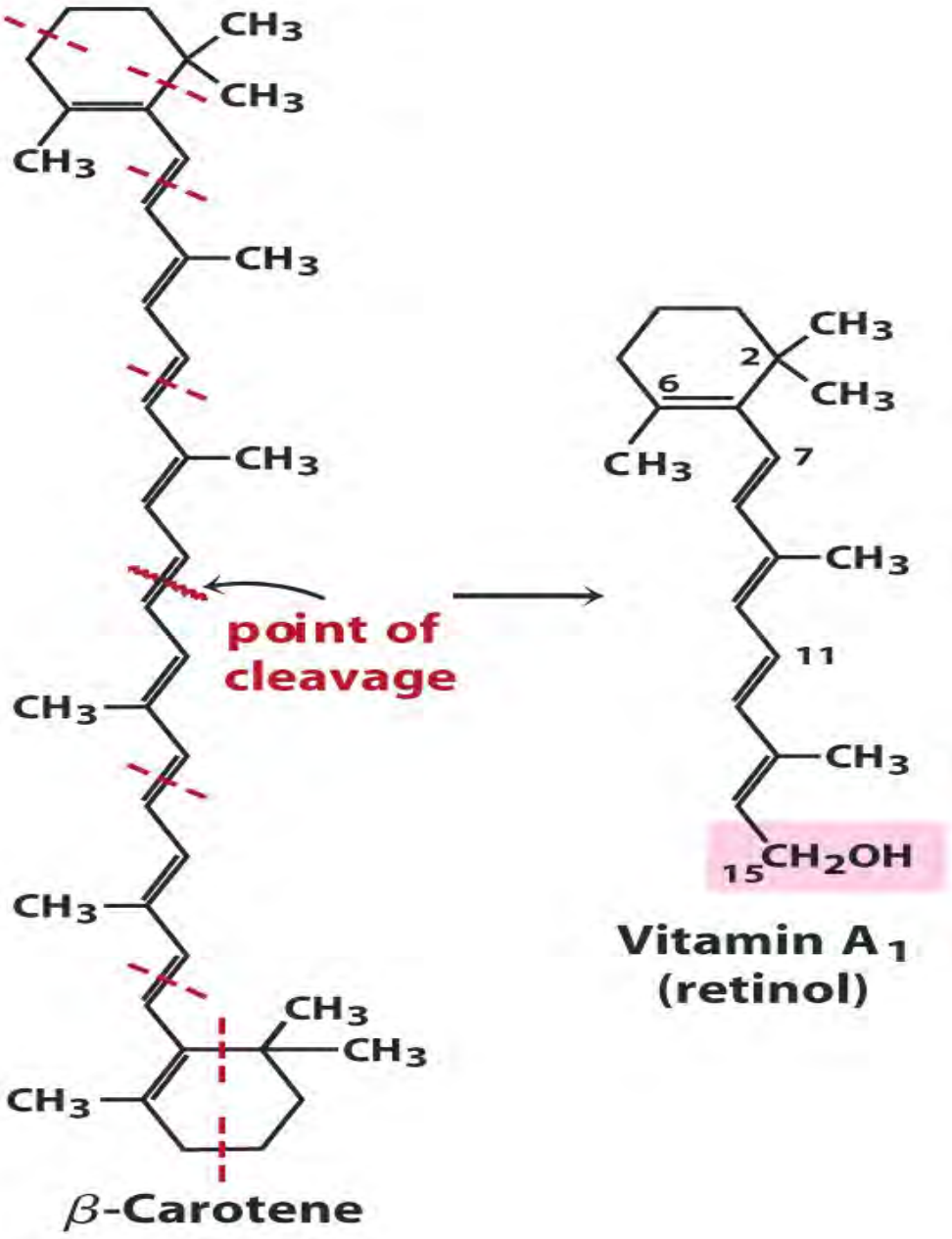


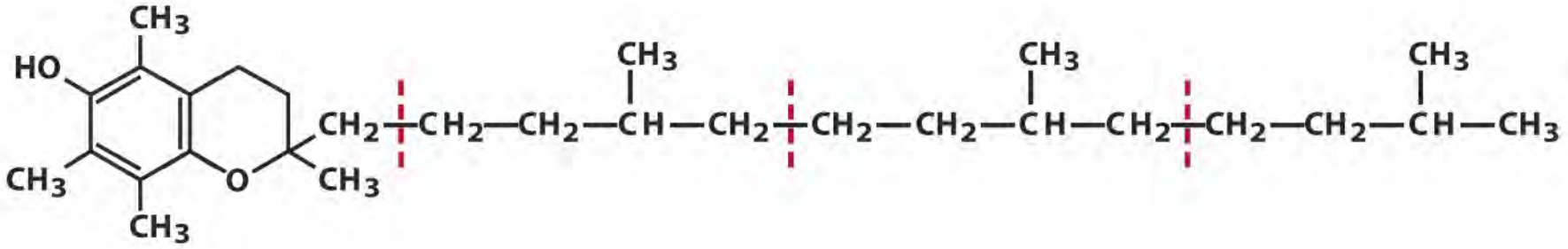
Prednisone


H3C
CH3
H3C
CH3
H3C
9
1
2
10
8
HO
3
4
5
6
7
7-Dehydrocholesterol
UV light
2 steps (in skin)
H3C
25
CH3
H3C
CH3
7
6
5
CH2
4
3
1
HO
2
Cholecalciferol (vitamin D3)

ISOPRENE

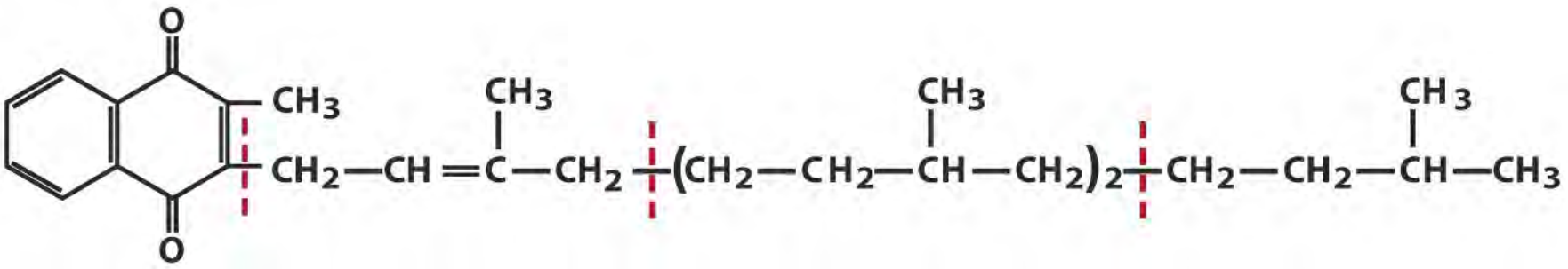



CH3
CH3
CH3
CH3
CH3
CH3
CH3
CH3
CH3
CH3
point of
cleavage
β-Carotene
CH3
2
6
CH3
CH3
7
CH3
11
CH3
15CH2OH
Vitamin A1
(retinol)



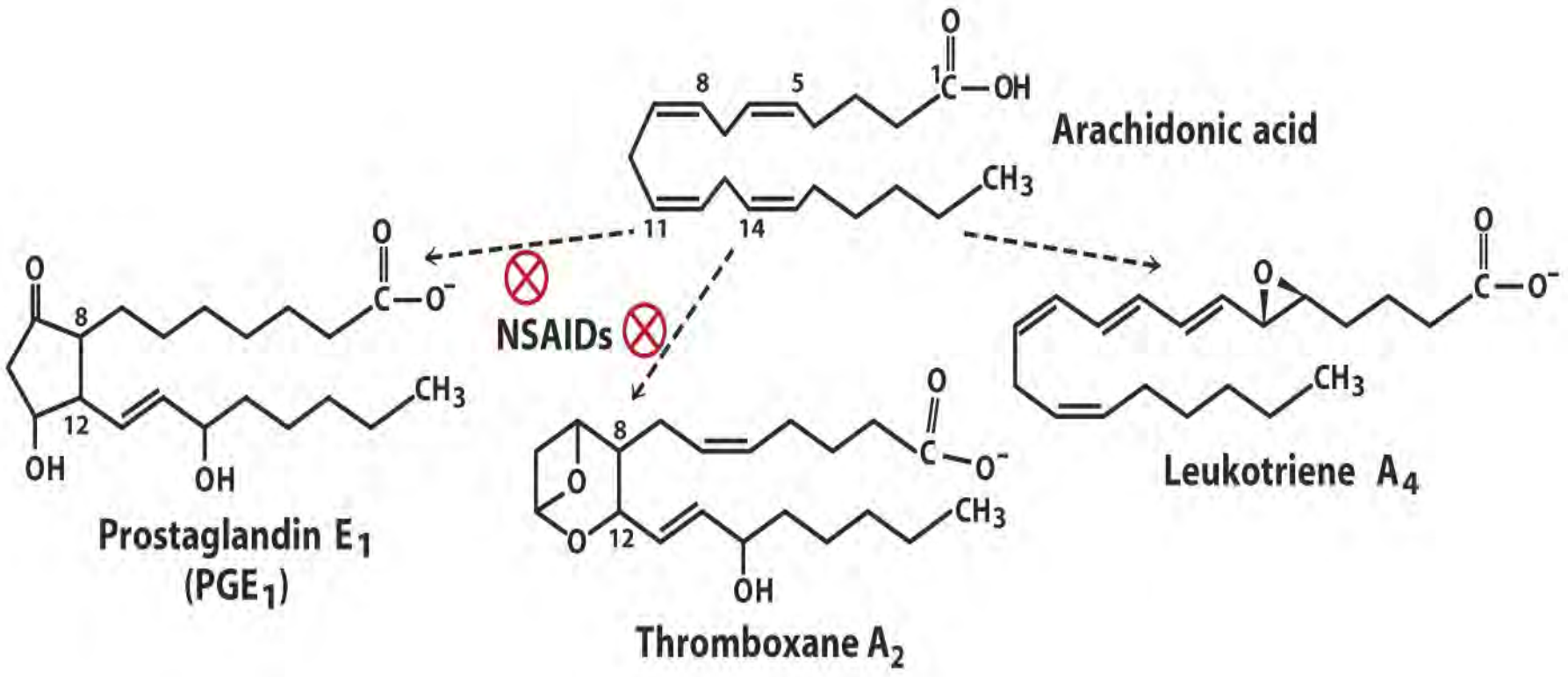
(a)

Vitamin E: an antioxidant



(b)

Vitamin K_1: a blood-clotting cofactor (phylloquinone)



Eicosanoids



Are You Getting It??



Which characteristics can be found in steroids, terpenes, or eicosanoids?

a) They contain ring structures.
b) They contain a carboxyl group.
c) They contain isoprene.
d) They are entirely hydrocarbon.
e) They are formed from a fatty acid.
f) They contain a hydroxyl group.



Are You Getting It??



Answer

Which characteristics can be found in steroids, terpenes, or eicosanoids?

a) They contain ring structures. *all*
b) They contain a carboxyl group. *eicosanoids*
c) They contain isoprene. *terpenes, steroids*
d) They are entirely hydrocarbon. *terpenes*
e) They are formed from a fatty acid. *eicosanoids*
f) They contain a hydroxyl group. *all*

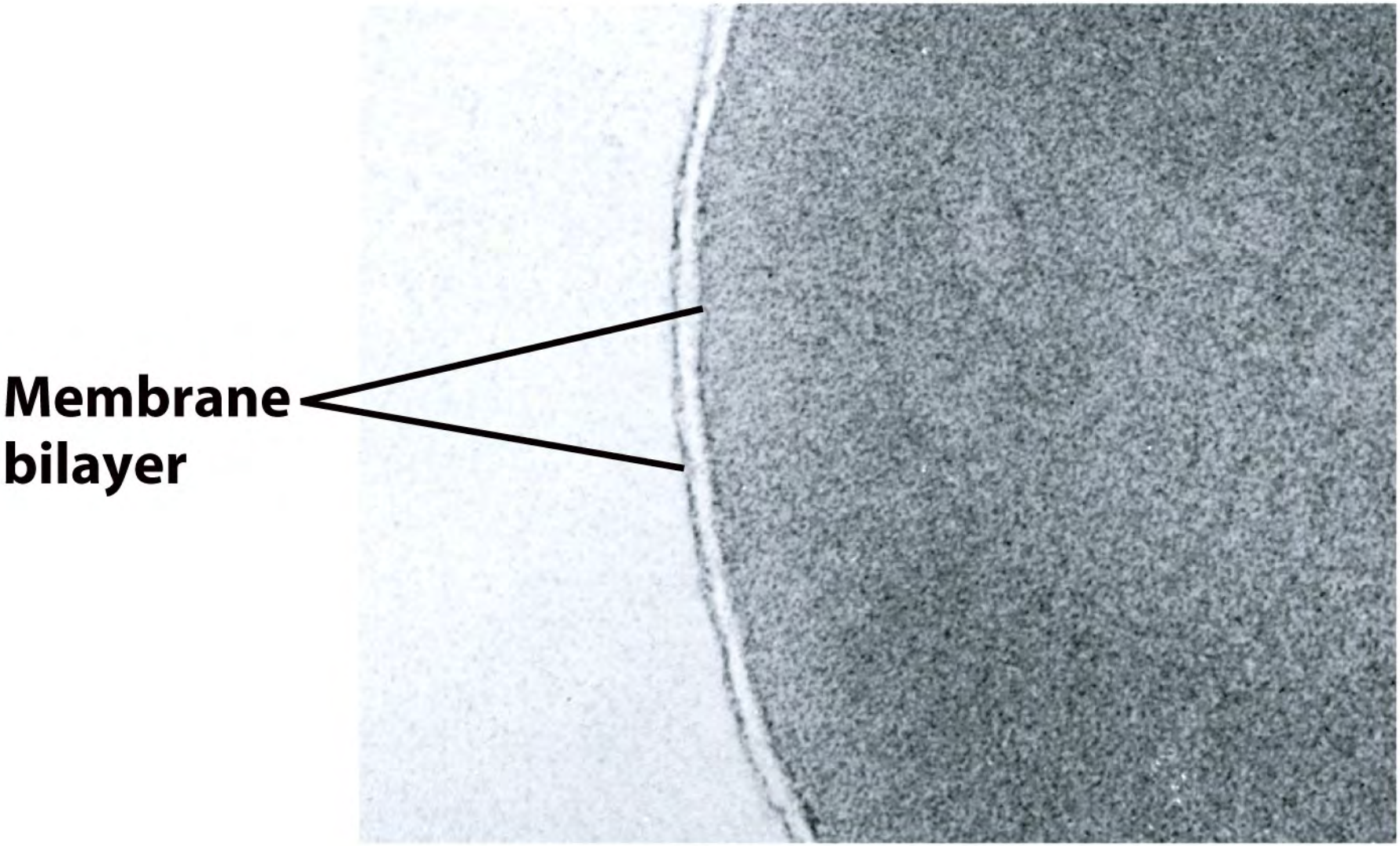
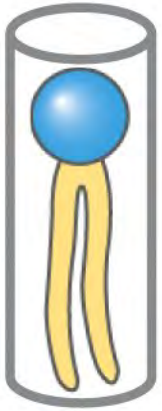

Membrane
bilayer

TABLE 11-1 Major Components of Plasma Membranes in Various Organisms

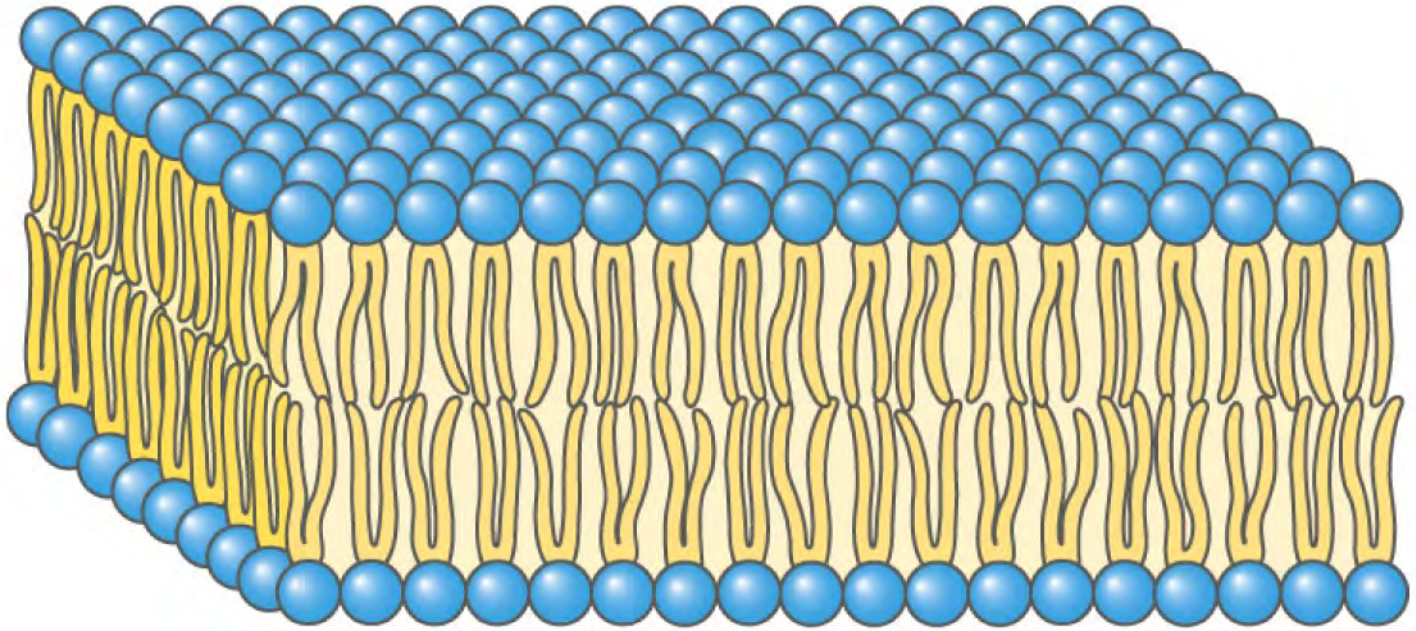
	Components (% by weight)				
	Protein	*Phospholipid*	*Sterol*	*Sterol type*	*Other lipids*
Human myelin sheath	30	30	19	Cholesterol	Galactolipids, plasmalogens
Mouse liver	45	27	25	Cholesterol	–
Maize leaf	47	26	7	Sitosterol	Galactolipids
Yeast	52	7	4	Ergosterol	Triacylglycerols, steryl esters
Paramecium (ciliated protist)	56	40	4	Stigmasterol	–
E. coli	75	25	0	–	–

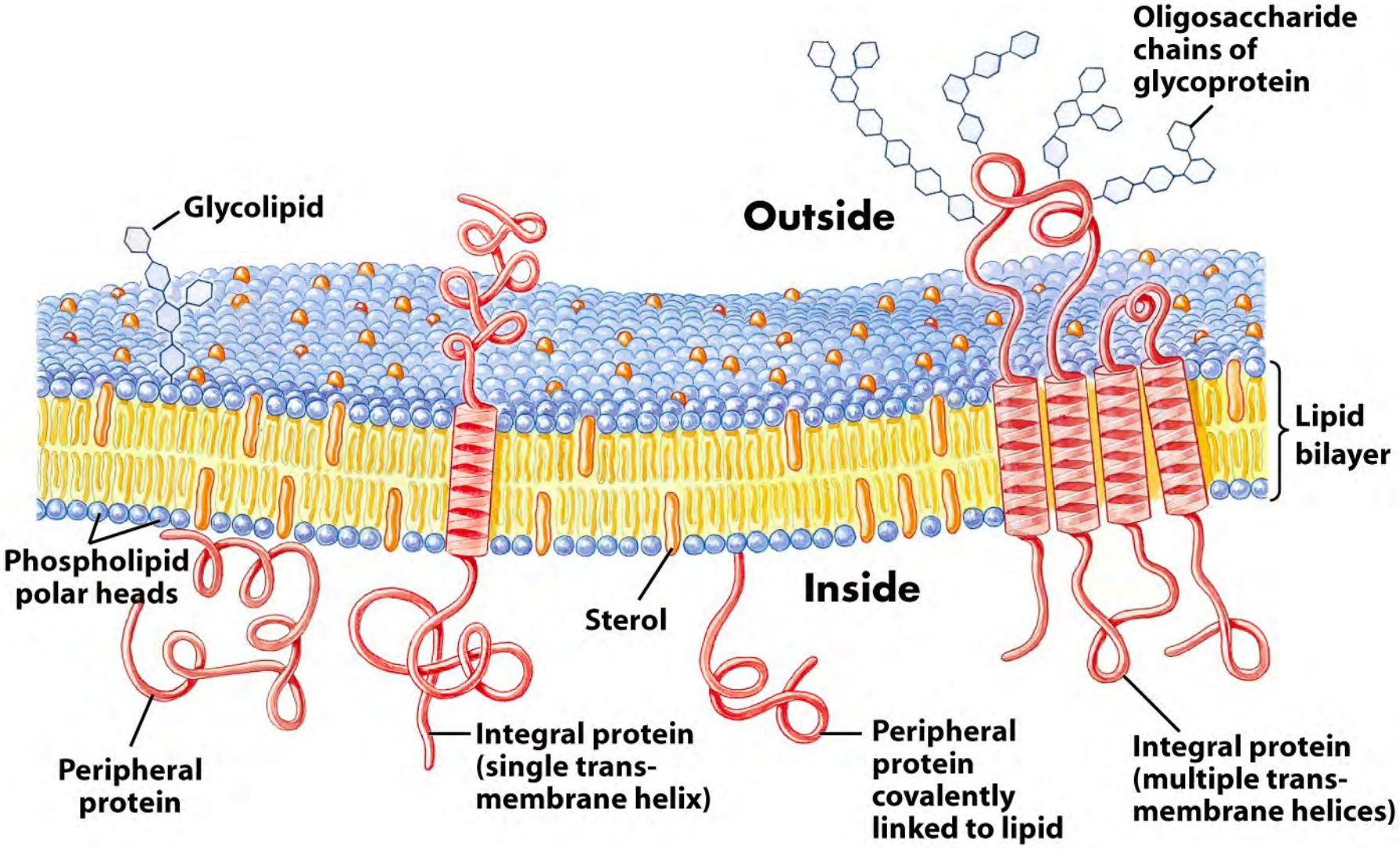
Note: Values do not add up to 100% in every case, because there are components other than protein, phospholipids, and sterol; plants, for example, have high levels of glycolipids.

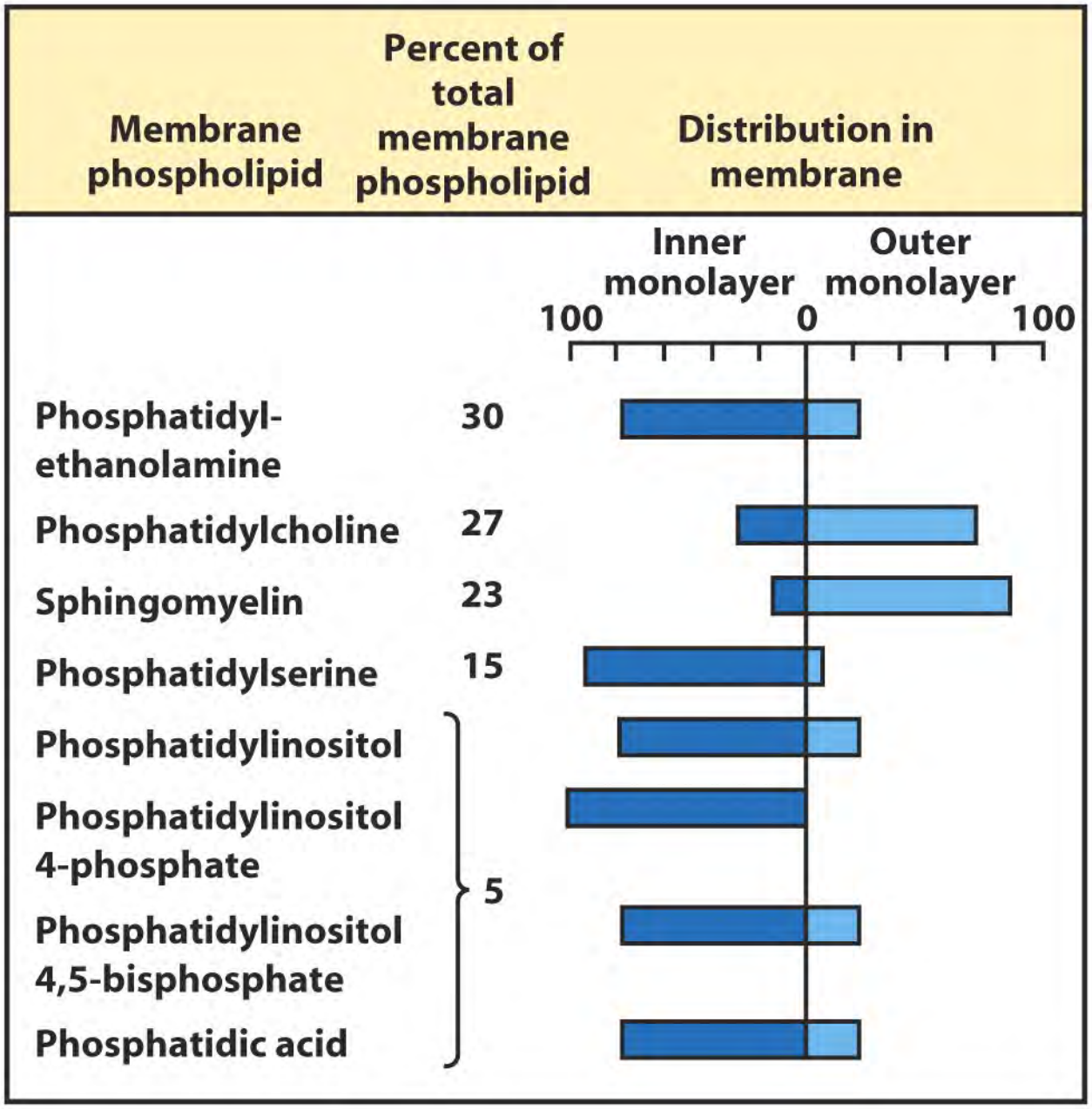
(b) Bilayer

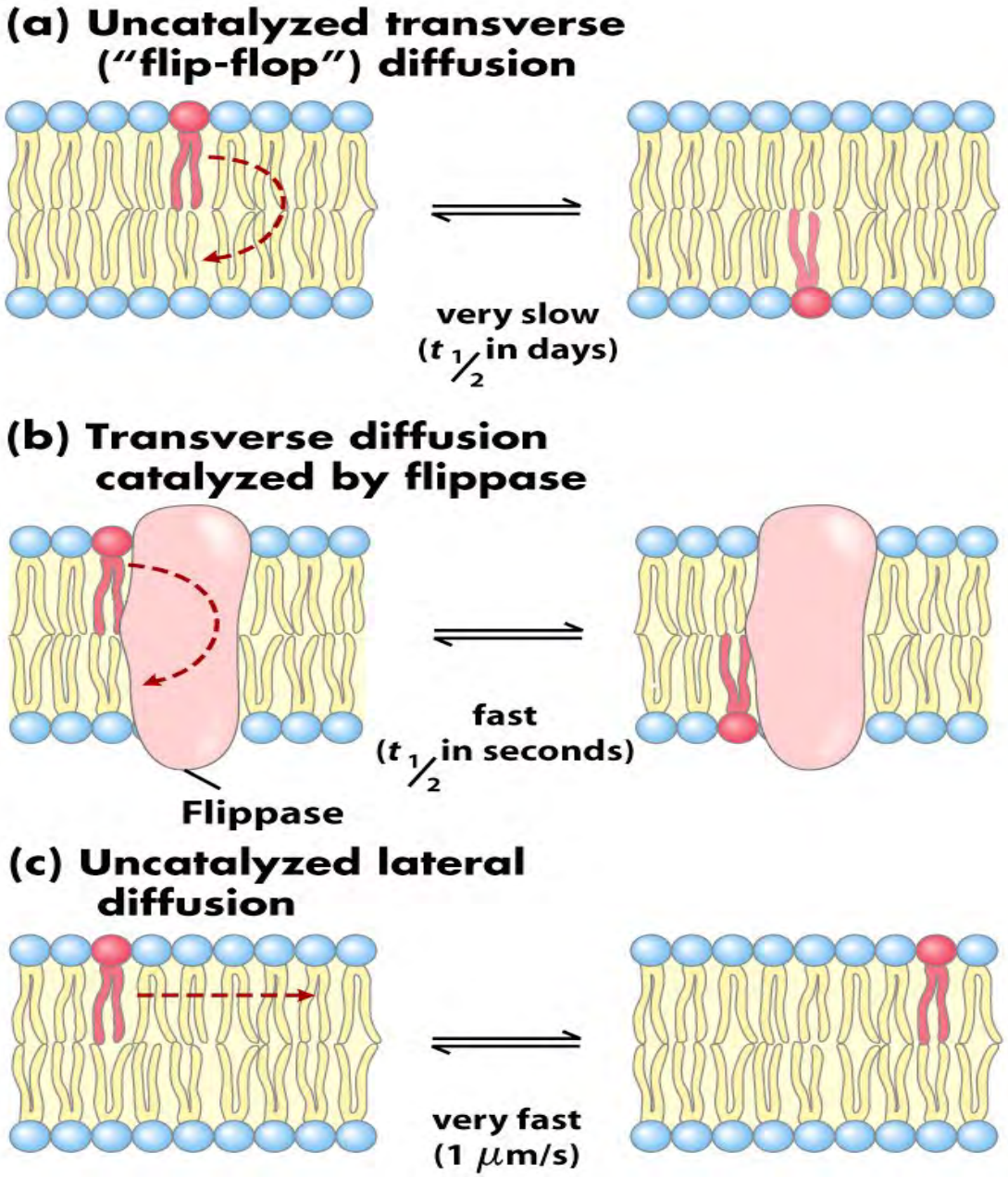


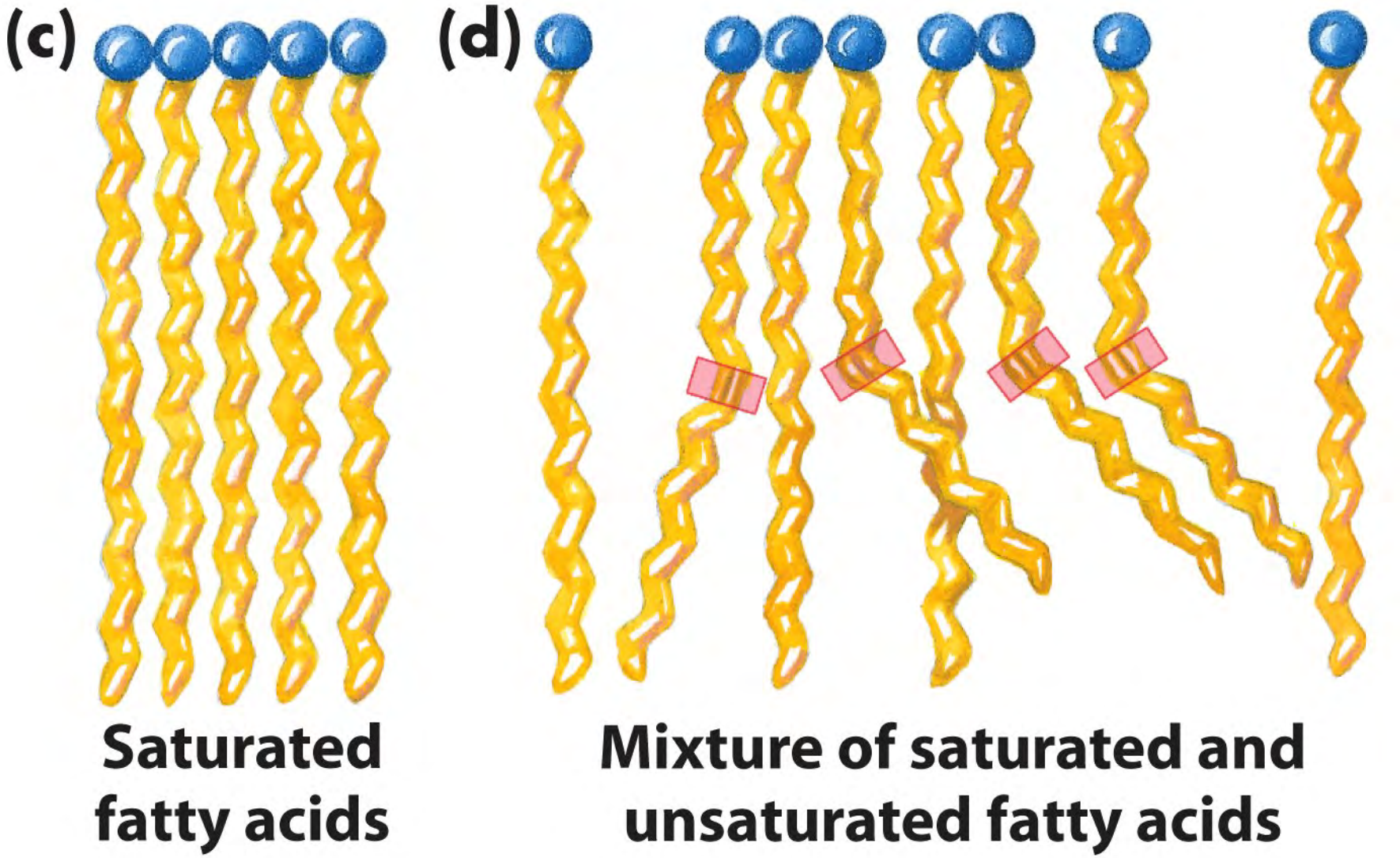
Individual units are cylindrical (cross section of head equals that of side chain)




Oligosaccharide chains of glycoprotein
Glycolipid
Outside
Lipid bilayer
Phospholipid polar heads
Sterol
Inside
Peripheral protein
Integral protein (single trans-membrane helix)
Peripheral protein covalently linked to lipid
Integral protein (multiple trans-membrane helices)


Membrane phospholipid
Percent of total membrane phospholipid
Distribution in membrane
Inner monolayer
Outer monolayer
100
0
100
Phosphatidyl-ethanolamine
30
Phosphatidylcholine
27
Sphingomyelin
23
Phosphatidylserine
15
Phosphatidylinositol
Phosphatidylinositol 4-phosphate
Phosphatidylinositol 4,5-bisphosphate
Phosphatidic acid
5


(a) Uncatalyzed transverse ("flip-flop") diffusion
very slow
($t_{1/2}$ in days)
(b) Transverse diffusion catalyzed by flippase
fast
($t_{1/2}$ in seconds)
Flippase
(c) Uncatalyzed lateral diffusion
very fast
(1 μm/s)


(c)
(d)
Saturated fatty acids
Mixture of saturated and unsaturated fatty acids



Are You Getting It??



Which properties are characteristic of membrane lipids?
(multiple answers)

a) The polar heads are on the membrane surfaces.
b) Types of lipids include triglycerides and sterols.
c) The two sides of the membrane are identical.
d) A lipid molecule can diffuse laterally.
e) A lipid molecule can flip from one side to the other.



Are You Getting It??



Answer

Which properties are characteristic of membrane lipids?

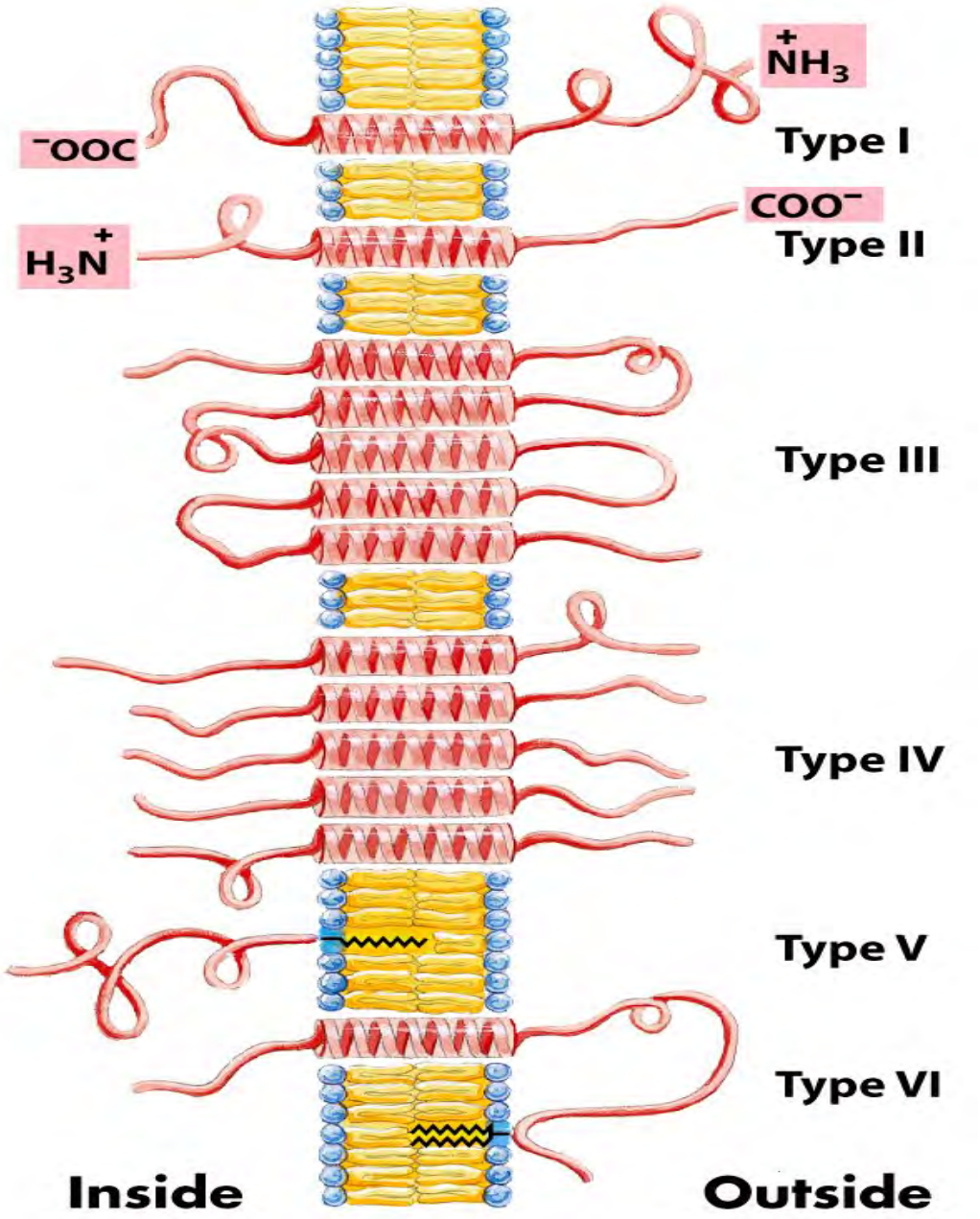
a) ***The polar heads are on the membrane surfaces.***

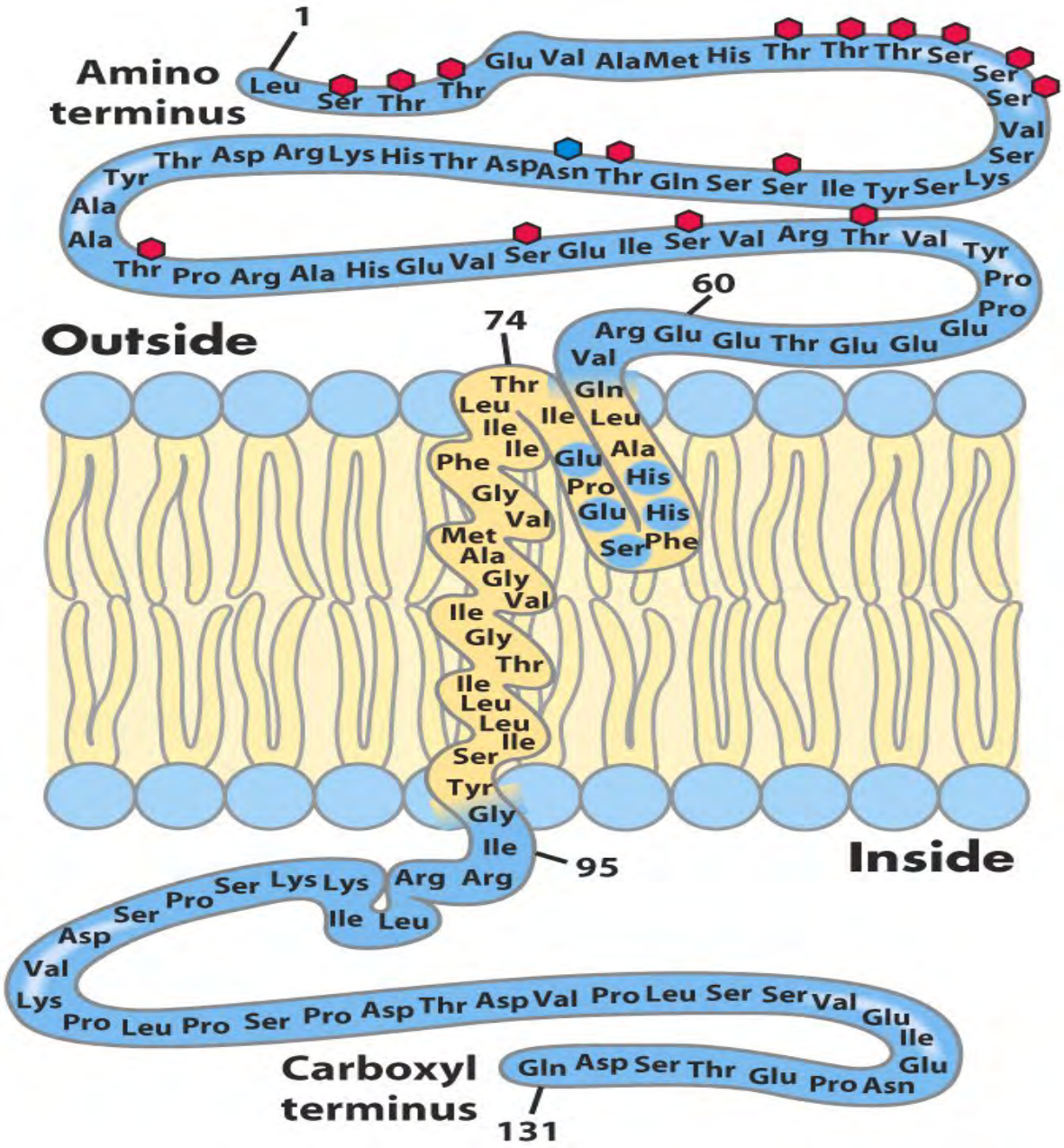
b) **Types of lipids include triglycerides and sterols.**

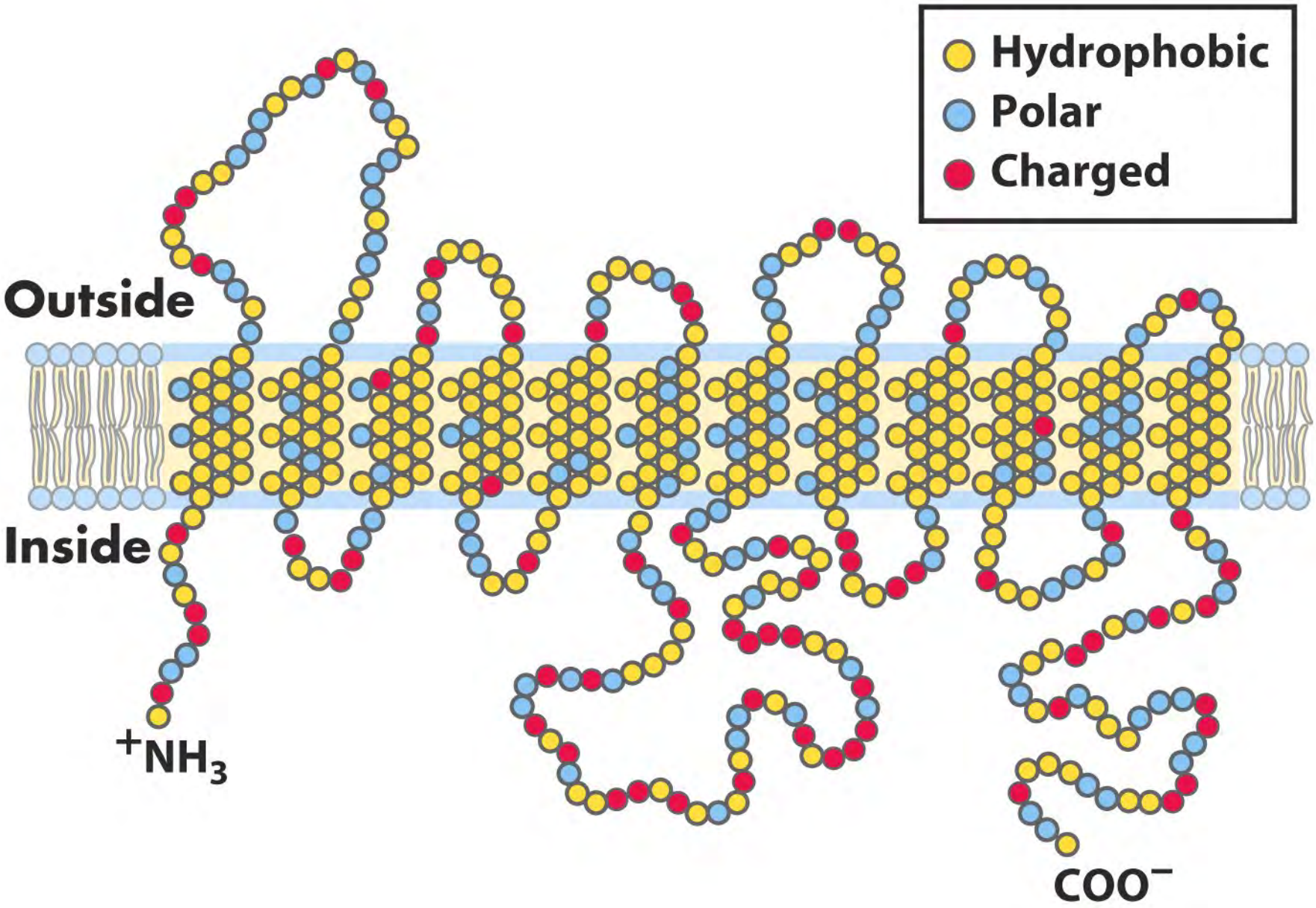
c) **The two sides of the membrane are identical.**

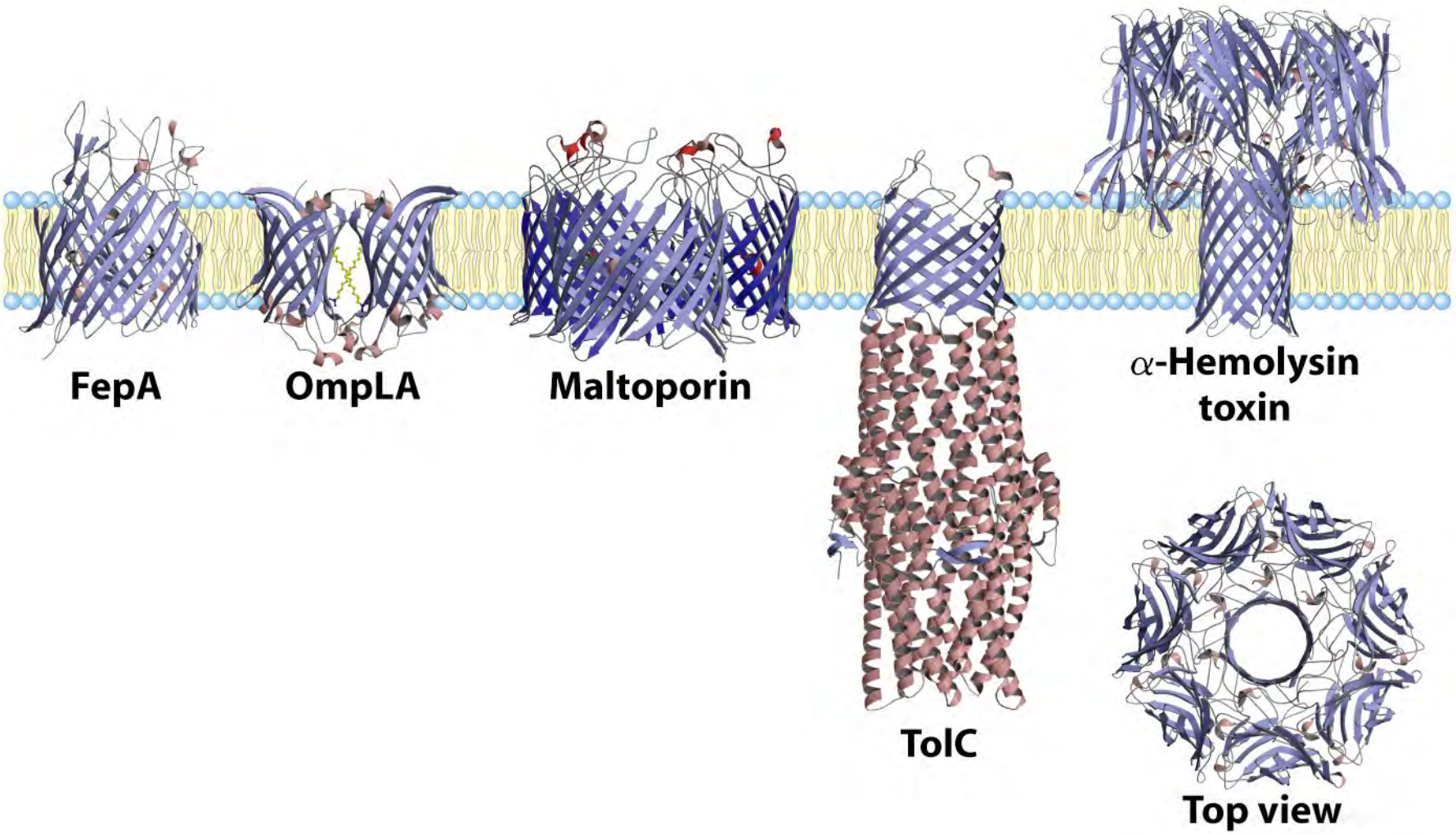
d) ***A lipid molecule can diffuse laterally.***

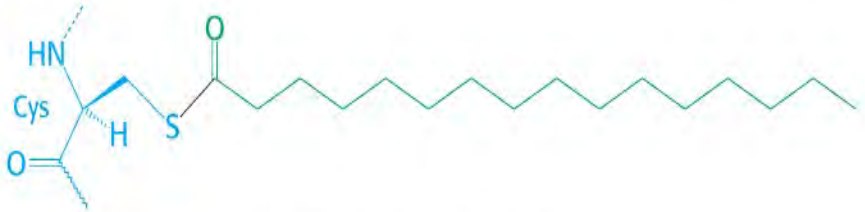
e) ***A lipid molecule can flip from one side to the other.***


$^{+}NH_3$
^{-}OOC
Type I
COO^{-}
H_3N^{+}
Type II
Type III
Type IV
Type V
Type VI
Inside
Outside

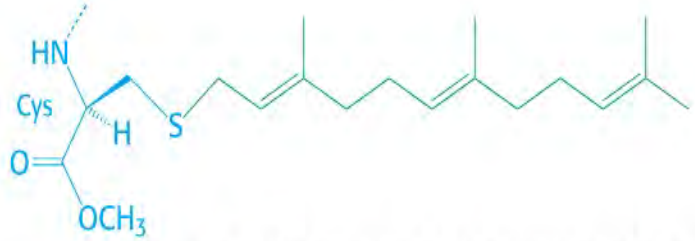

1
Amino terminus
Leu Ser Thr Thr Glu Val Ala Met His Thr Thr Thr Ser Ser Ser Ser Val Ser Lys
Tyr Thr Asp Arg Lys His Thr Asp Asn Thr Gln Ser Ser Ile Tyr Ser
Ala
Ala
Thr Pro Arg Ala His Glu Val Ser Glu Ile Ser Val Arg Thr Val Tyr Pro Pro Glu
60
74
Outside
Arg Glu Glu Thr Glu Glu
Val
Thr Leu Ile Ile Ile Phe Gly Val Met Ala Gly Val Ile Gly Thr Ile Leu Leu Ile Ser Tyr Gly Ile
Gln Leu Ala His Glu His Ser Phe
Pro
95
Inside
Arg Arg Lys Lys Ser Pro Ser Asp Val Lys Pro Leu Pro Ser Pro Asp Thr Asp Val Pro Leu Ser Ser Val Glu Ile Glu
Ile Leu
Carboxyl terminus
Gln Asp Ser Thr Glu Pro Asn
131


Hydrophobic
Polar
Charged
Outside
Inside
+NH3
COO−

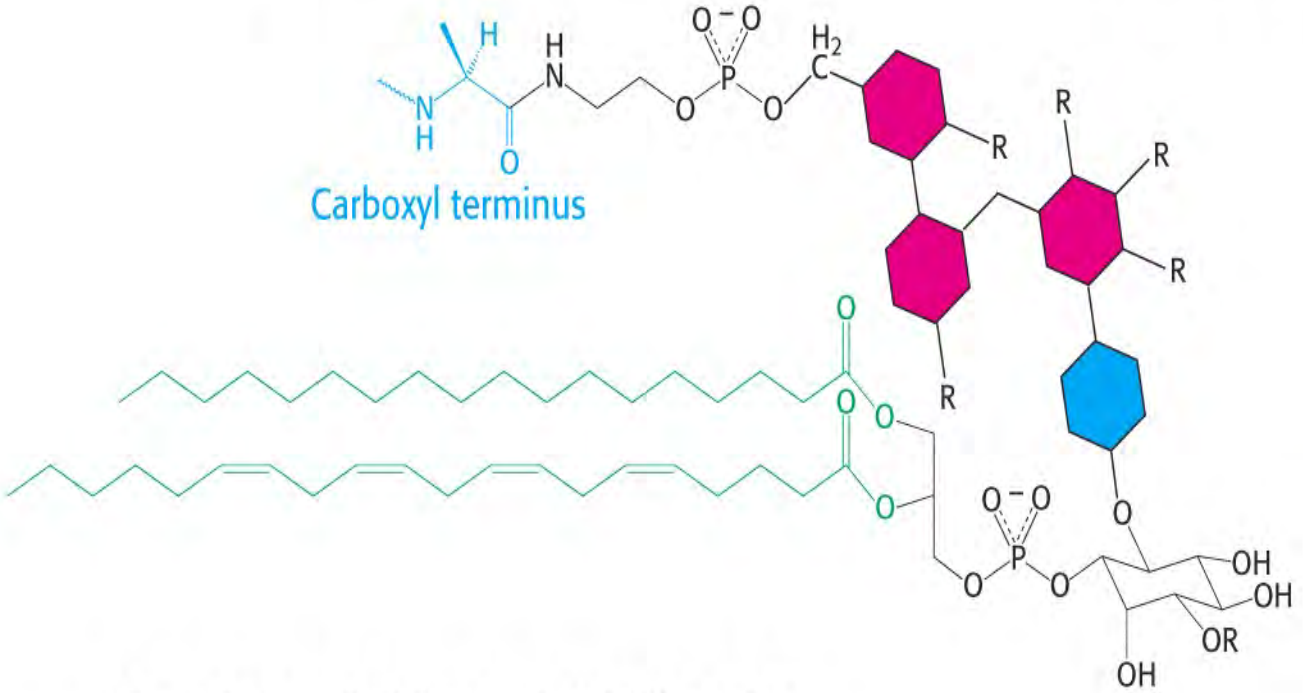

FepA
OmpLA
Maltoporin
TolC
α-Hemolysin toxin
Top view



S-Palmitoylcysteine



C-terminal S-farnesylcysteine methyl ester



Glycosyl phosphatidyl inositol (GPI) anchor



Are You Getting It??



Which properties are characteristic of integral membrane proteins? ***(multiple answers)***

a) They contain a large number of hydrophobic R-groups.
b) They are bound loosely to the membrane surface.
c) They are covalently linked to fatty acids.
d) They contain α-helices that cross the membrane.
e) They are symmetrically oriented in the membrane.



Are You Getting It??



Answer

Which properties are characteristic of integral membrane proteins?

a) ***They contain a large number of hydrophobic R-groups.***

b) **They are bound loosely to the membrane surface.**

c) **They are covalently linked to fatty acids.**

d) ***They contain α-helices that cross the membrane.***

e) **They are symmetrically oriented in the membrane.**

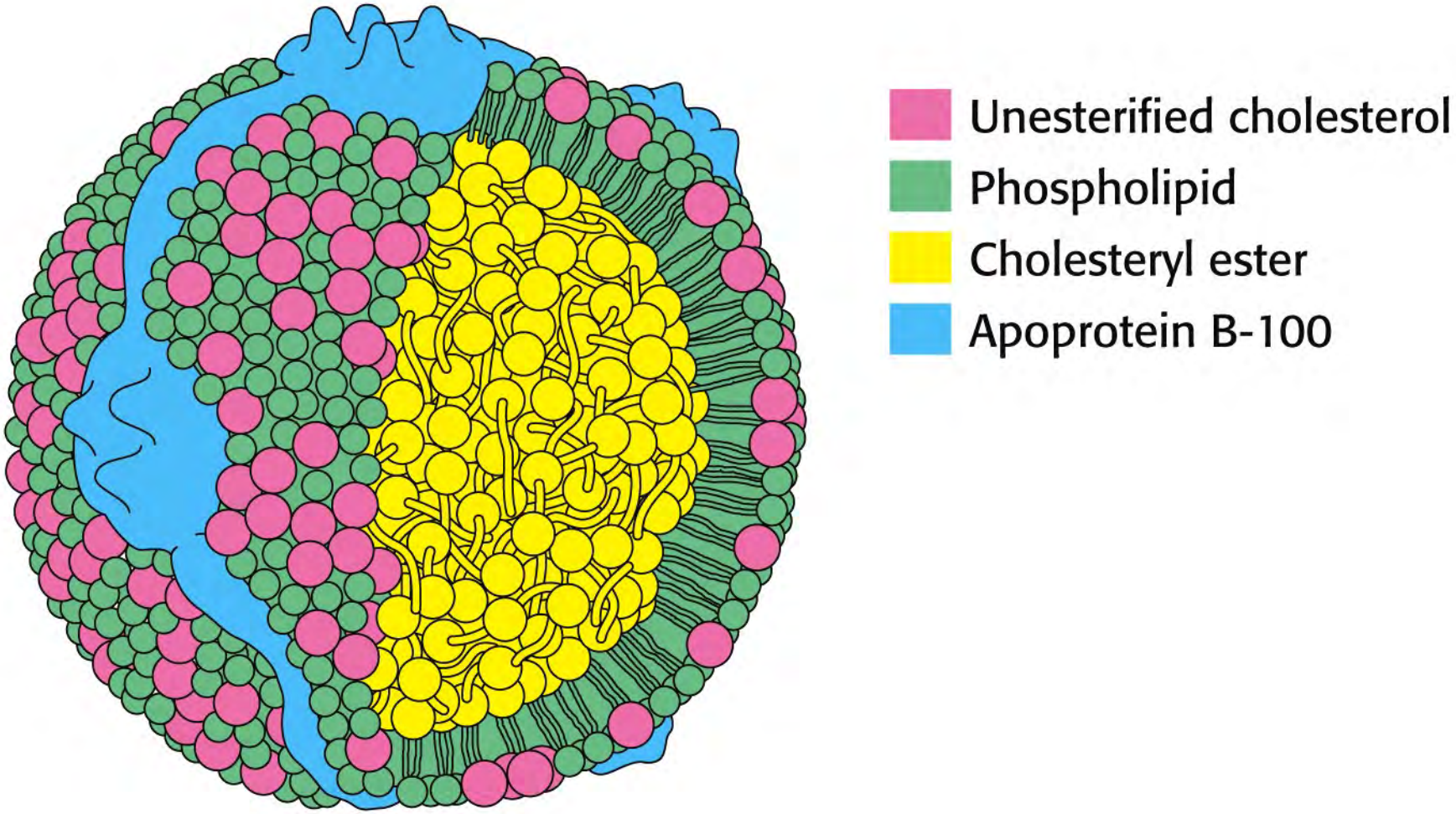
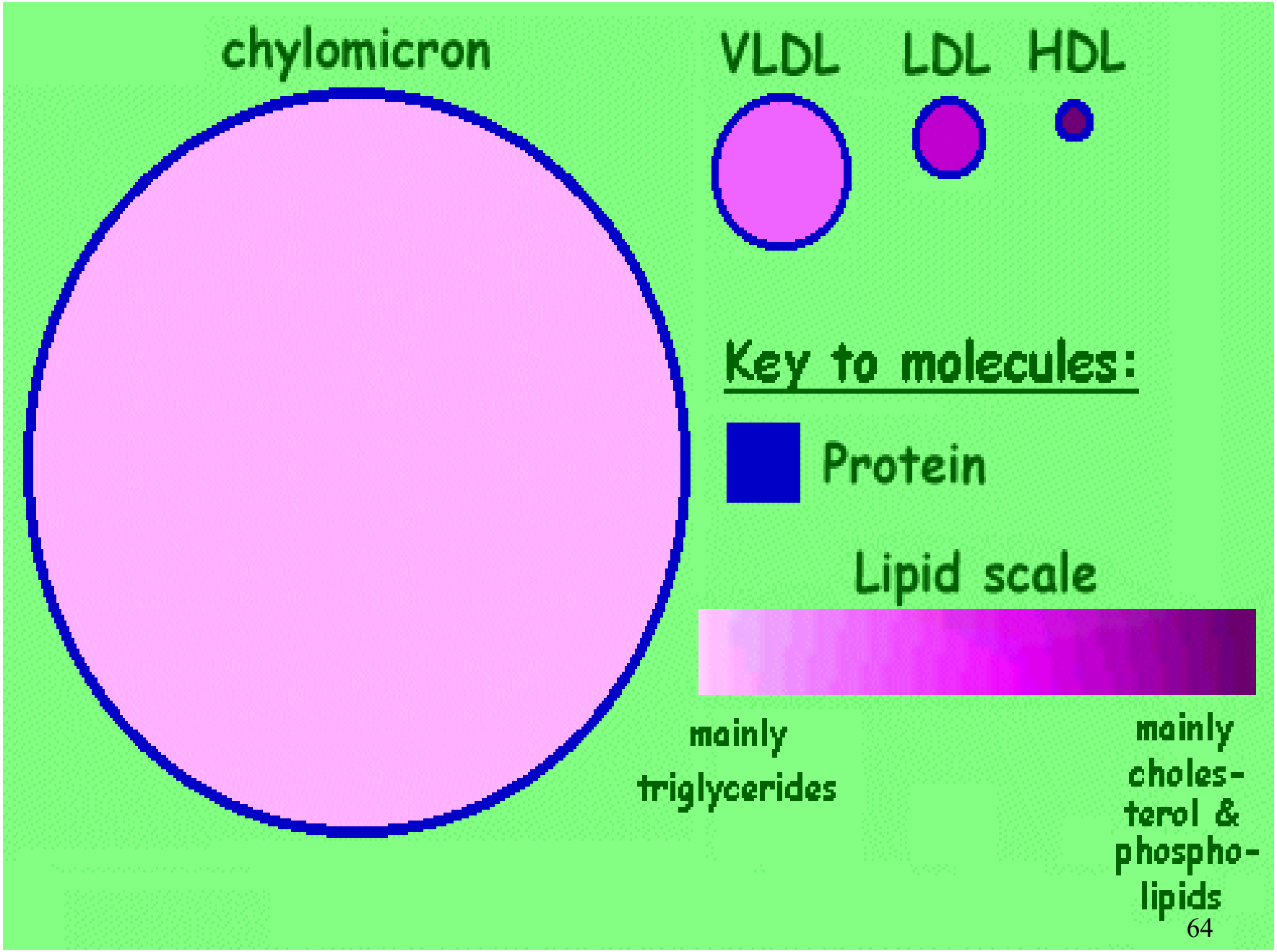

Unesterified cholesterol
Phospholipid
Cholesteryl ester
Apoprotein B-100

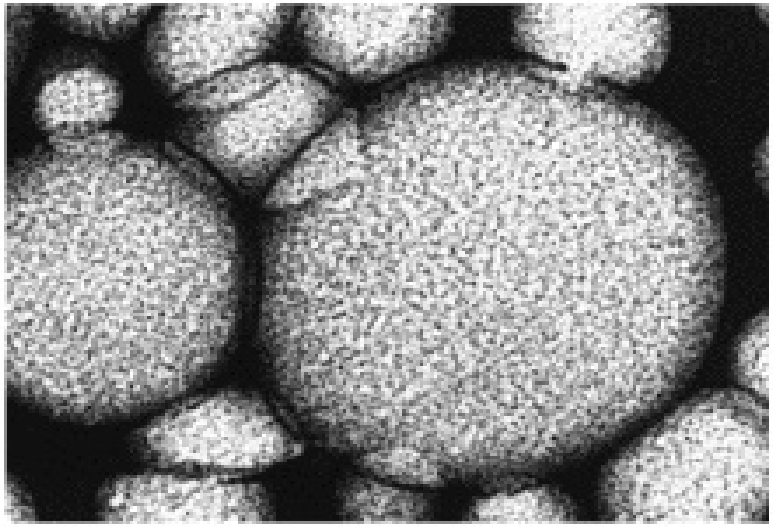
Table 12.2 Composition and Properties of Human Lipoprotein

Lipoprotein Class	Density (g/mL)	Diameter (nm)	Composition (% dry weight)			
			Protein	Cholesterol	Phospho-lipid	Triacyl-glycerol
HDL	1.063–1.21	5–15	33	30	29	8
LDL	1.019–1.063	18–28	25	50	21	4
IDL	1.006–1.019	25–50	18	29	22	31
VLDL	0.95–1.006	30–80	10	22	18	50
Chylomicrons	< 0.95	100–500	1–2	8	7	84

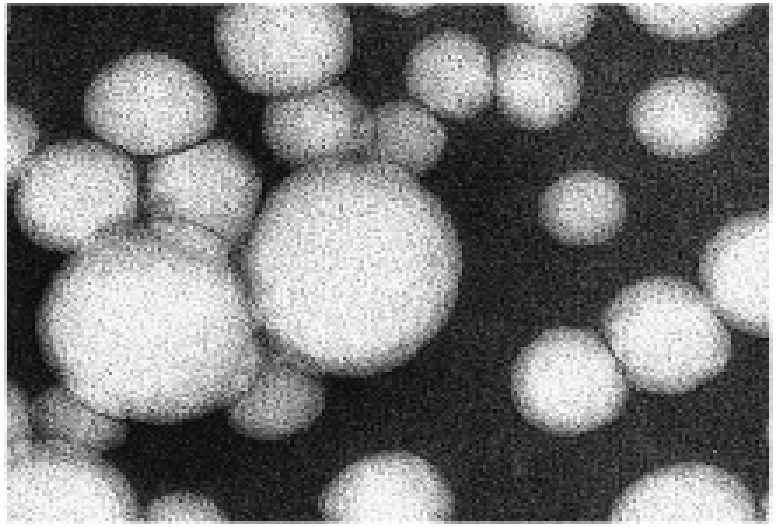
Adapted from Brown, M., and Goldstein, J., 1987. Chapter 315: The hyperlipoproteinemias and other disorders of lipid metabolism. In Braunwald, E., et al., eds., *Harrison's Principles of Internal Medicine,* 11th ed. New York: McGraw-Hill; and Vance, D., and Vance, J., eds., 1985. *Biochemistry of Lipids and Membranes.* Menlo Park, Calif.: Benjamin Cummings.

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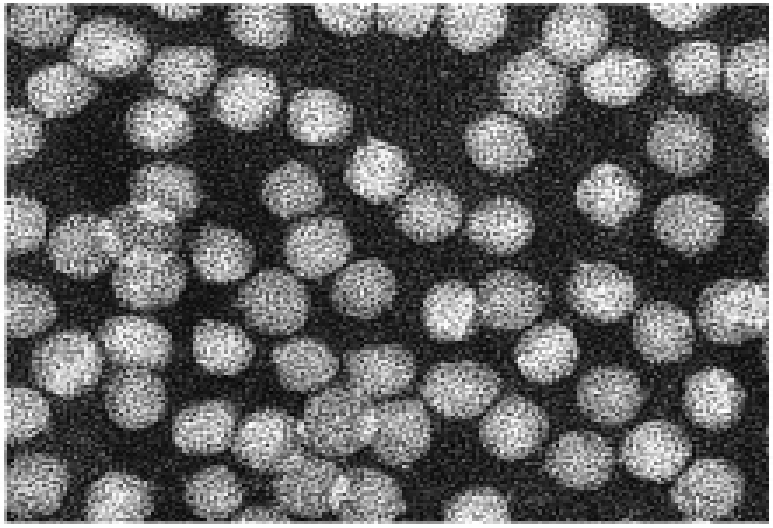

chylomicron
VLDL
LDL
HDL
Key to molecules:
Protein
Lipid scale
mainly triglycerides
mainly cholesterol & phospholipids



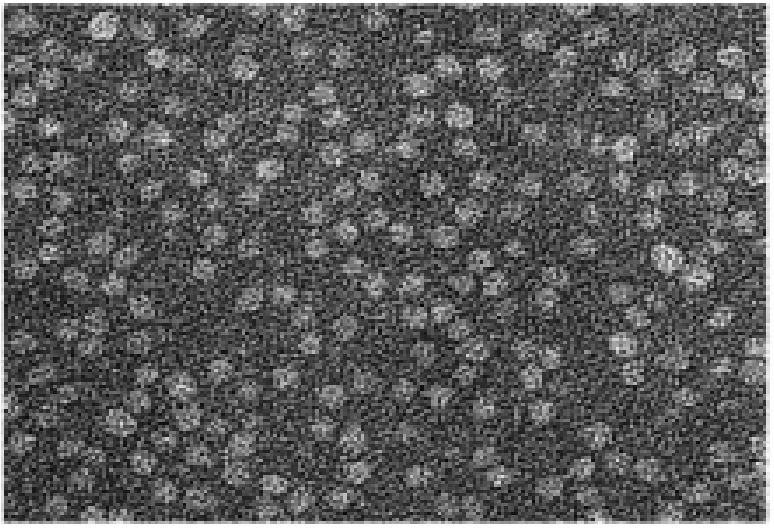
Chylomicrons (50–200 nm diameter)



VLDL (28-70 nm diameter)



LDL (20-25 nm diameter)



HDL (8-11 nm diameter)

(b)